RBS 497

INITIAL STUDY OF THE FORMER KINGSTON COAL GASIFICATION PLANT SITE





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Prepared for

Ontario Ministry of the Environment
Waste Management Branch

FINAL REPORT

H88-026

July 27, 1988

1988 - Her Majesty the Queen in Right of Ontario as represented by the Minister of the Environment

ACKNOWLEDGEMENT AND DISCLAIMER

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EXECUTIVE SUMMARY

Initial site investigations of the former Kingston Coal Gasification Plant located in the blocks bounded by Queen, Ontario, Place D'Armes and King Streets in Kingston have been completed to determine if potentially hazardous wastes remain on-site and if present, to determine how the wastes occur on the site and whether or not the wastes are impacting on human health and/or the environment.

The site investigations were completed in three phases. Phase 1 studies were reconnaissance level investigations including a historical review, a ground probing radar survey, and soil and soil gas sampling designed to identify historical waste storage locations and to assist in planning subsequent phases. Phase 2 studies provided a more in depth investigation of the nature and extent of on-site contamination. These studies included: drilling; soil sampling; monitoring well installation; groundwater sampling; surface water and sediment sampling; and utility line and building sump inspections. The Phase 3 component provided documentation of the methodologies and results with interpretations, an environmental impact assessment and recommendations based on the results.

The Kingston Gas Plant was in operation from 1848 to the early 1950s. During its operation the gas generating method changed from a coal gasification, to a water gas to a carburetted water gas process. Because of the changes in processes, some of the gas plant and waste storage facilities changed locations several times and therefore locations of contaminated areas are not predictable.

Presently the former gas plant property is occupied by the Kingston Public Utilities bus garages and offices, the Kingston police station and several commercial businesses. In some cases, the original gas plant buildings (i.e., purifier house and gas holder house) remain on-site and are in use while in other cases the structures (i.e., gas

EXECUTIVE SUMMARY (cont'd)

holding tank and coal shed) have been demolished and replaced with buildings. Evidence of some of the waste storage locations (i.e., gas holding tanks) are still apparent on the property.

Site investigations have identified fill and clay overburden overlying bedrock to be thin and relatively free of evidence of coal tar wastes. Coal tar was, however, found in fill material north of the electrical substation and on top of the former main gas holder on the corner of King and Place D'Armes Streets. The limestone bedrock was found to contain free coal tar and contaminated groundwater in four test holes drilled on-site and one test hole drilled off-site. Coal tar was primarily found within fractures and bedding planes in the bedrock at depths of about 3 to 12 metres below surface.

Shallow groundwater in the area of the former gas plant is affected by man-made structures and activities. The building sump in the police station basement is the low point in the groundwater system and groundwater surrounding the police station flows to, and is collected by the sump. The groundwater flow directions may also be affected by the sanitary trunk sewer which runs along Ontario and Place D'Armes Streets at a depth of about 6 metres below surface.

The groundwater in the area of the former gas plant was found to be contaminated with coal tar products. High concentrations of light aromatic hydrocarbons, polycyclic aromatic hydrocarbons (PAH) and phenols which are not normally found in groundwater were found in five of the six monitoring wells that were sampled. Concentrations of phenols (i.e., 2 to 430 ppb) and benzene (i.e., 130 to 65000 ppb), for example, exceed MOE drinking water objectives and water quality objectives. Groundwater, entering the sump of the police station, contains low levels of PAH as well. The coal tar and contaminated

EXECUTIVE SUMMARY (cont'd)

groundwater in the bedrock does not appear to have an impact on the surface water and sediment quality in Anglin Bay or Lake Ontario. PAH were not detected in surface water samples and only low levels of PAH which are considered to be background levels, were found in the sediments of Anglin Bay.

The extent of contamination includes the entire two block area of the former gas plant and some of the area north of King and Place D'Armes Streets. Contamination probably extends off of the gas plant property but additional work may be required to define the off-property extent of contamination.

The contaminated zones are largely confined under at least 1.5 m of soil in the bedrock and this acts to prevent direct contact with the hazardous material. Similarly air quality impacts are negligible because the waste is not exposed at surface. Odours associated with the police station sump are evident only when the cover is removed but the impact on ambient air quality is considered to be of low concern with the cover in place. The groundwater in the area is highly contaminated but is of low concern because the groundwater is not used as a water supply. The coal tar and contaminated groundwater appear to have little environmental impact on surface waters based on the limited samplings of this initial investigation. It is possible that free coal tar and/or contaminated groundwater is discharging to Anglin Bay or Lake Ontario through the bedrock although dilution along the pathway may be sufficient to reduce the concentration sufficiently to result in an immeasurable impact.

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1. INTRODUCTION AND BACKGROUND

In response to the discovery of manufactured gas plant wastes in several communities in Ontario in 1986, the Ontario Ministry of the Environment (MOE) commissioned a study to identify and assess the potential environmental impact of former manufactured gas plant waste sites in the Province of Ontario. This study, "Inventory of Coal Gasification Plant Waste Sites in Ontario", was completed in April 1987 by Intera Technologies Ltd. (INTERA) and identified 41 manufactured gas plants in 36 different communities.

At a number of these sites identified in the study, little or nothing was known about the fate of waste materials that were produced in the gasification process. In order to provide information on the occurrence of waste material on-site and the potential for environmental impact, the MOE contracted Intera Technologies Ltd. to perform initial site investigations at the former Kingston Coal Gas Plant.

This report documents the methodology, results, interpretations and recommendations that were derived from these initial investigations.

1.1 STUDY OBJECTIVES

As stated in the terms of reference (Appendix A) the objectives of the study were:

i) determine whether or not coal gasification plant wastes are present;

ii) if present, determine how these wastes occur on-site (in storage tanks, in soil, etc.), and obtain some indication of their distribution;

iii) if present, determine whether the wastes are contained, or whether the wastes, or contaminated water, or both, may be moving off-site;

iv) if present, determine whether or not the wastes are impacting on, or pose an imminent threat of impact on, human health and safety, or the environment, or both.

In addition to these general objectives, the following objective relates specifically to the Kingston site:

- What is the type and extent of the tar contamination that was found in a sewer excavation in 1986 on King Street north of Place d'Armes Street? Is contamination from this area likely to reach Lake Ontario.

1.2 STUDY SCOPE

To satisfy the study objectives, a three phase work plan was developed.

Phase 1 work was designed to identify buried waste sources and to provide a preliminary indication of the distribution of on-site waste. Phase 1 activities involved performing a review of existing information including a historical review of waste storage locations. Using the historical evidence, a ground probing radar survey was carried out to confirm and identify gas plant structures. Soil sampling, using a hand auger, and soil gas sampling, using a portable organic vapour meter/gas chromatograph, were used to probe the shallow ground surface for evidence of waste. Waste was detected on-site and therefore Phase 2 studies were designed to define the extent of the waste and to determine if the waste, contaminated groundwater or air were migrating off-site or creating an environmental impact.

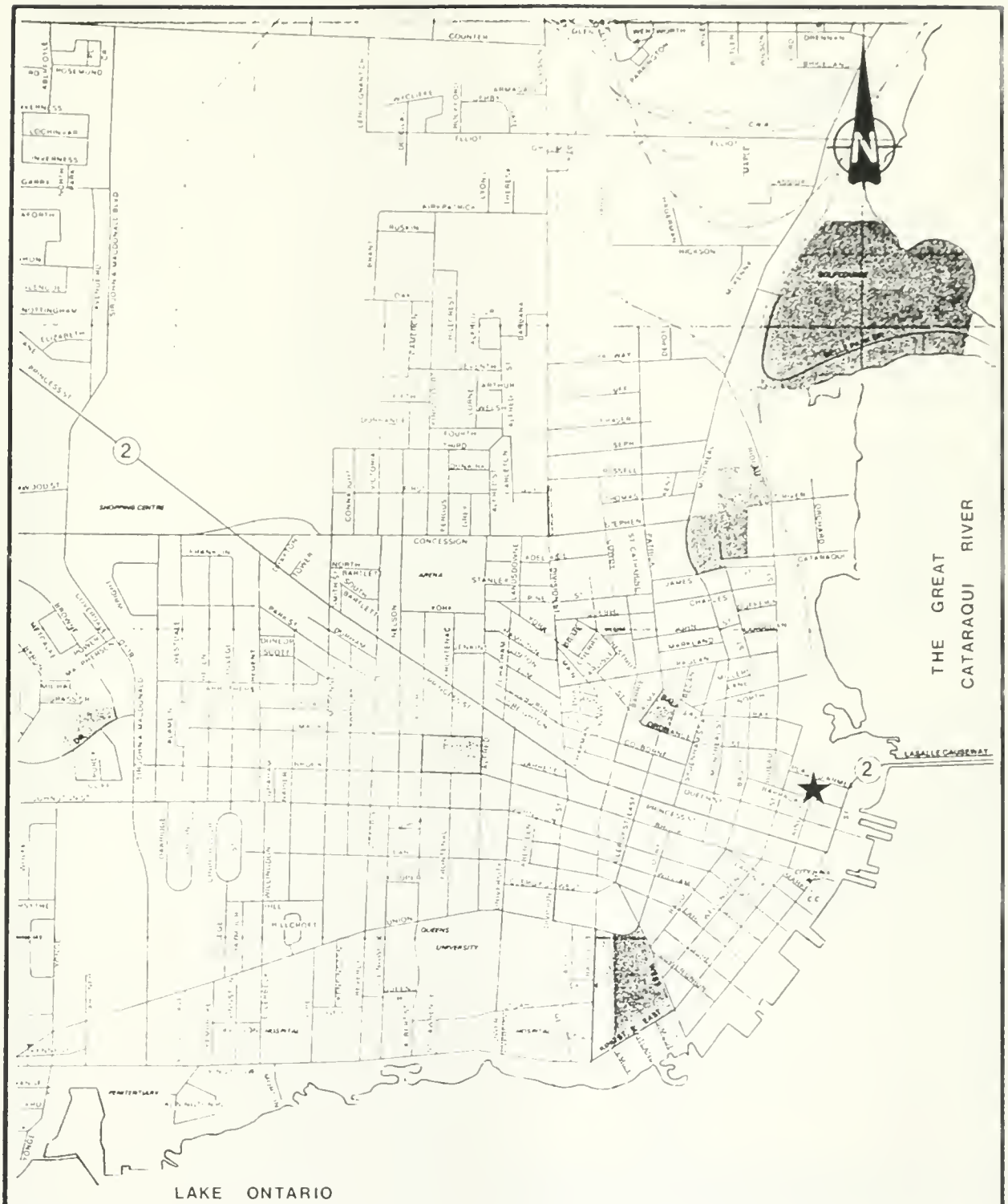
The Phase 2 studies were conducted using an air monitoring program and a health and safety program. Each of the potentially contaminated areas identified in Phase 1 were investigated using a drilling program and soil/rock sampling program. Groundwater contamination was investigated in a monitoring well installation and sampling program and surface water was studied by sampling of the water and sediments in adjacent water bodies. Finally, all on-site utility lines and building sumps were visually inspected for gas plant wastes.

The Phase 3 component of the study included the reporting and documentation of the methodology, results, interpretations and recommendations of the site investigations.

1.3 SITE DESCRIPTION

"The Kingston gas works operated for over 100 years from 1848 to 1957 on a 1.6 hectare site located north and south of Barrack Street between King Street East and Ontario Street, and Queen Street and Place D'Armes Street (Figure 1.1). The main gas works was established south of Barrack Street and auxiliary gas holders were situated north of Barrack Street. The gas works was a retort coal gasification facility, a carburetted water gas facility and finally a propane air gas plant. The Kingston Public Utilities Commission (PUC) assumed operation of the gas works in 1913" (INTERA, 1987).

"The main gas works site (Figure 1.2) is now occupied by the PUC bus repair garage, parking lot, and office, the Kingston police underground parking garage, a Kingston Hydro substation, and retail stores. The auxiliary gas holding area is now occupied by the PUC bus transit garage and parking lot. Both properties are located in uncontrolled-access, public use areas. The former gas works site is located about 150 m southwest of the mouth of the Great Cataraqui River. The river has recreational use" (INTERA, 1987).

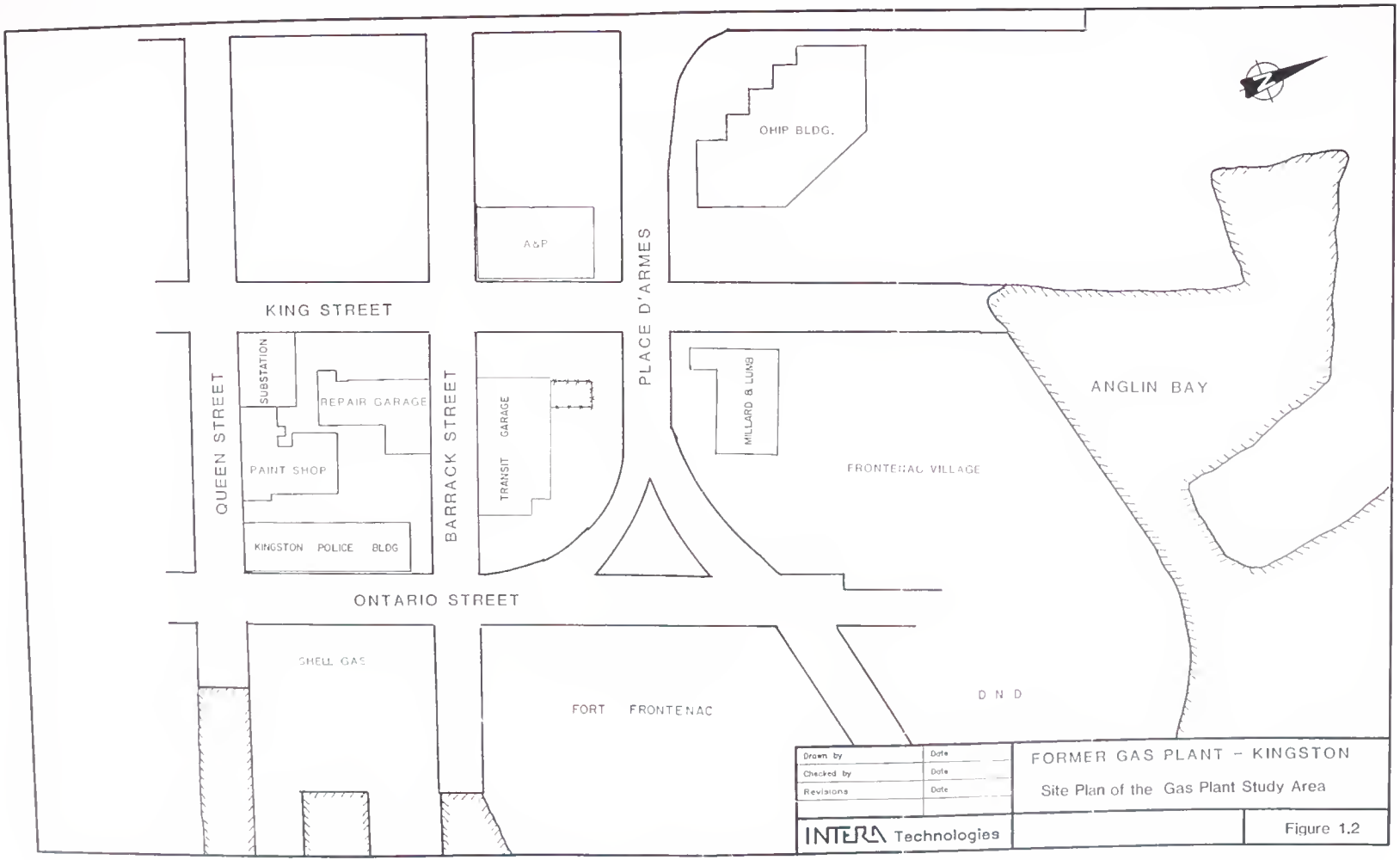


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City of Kingston, showing location of former gas works.

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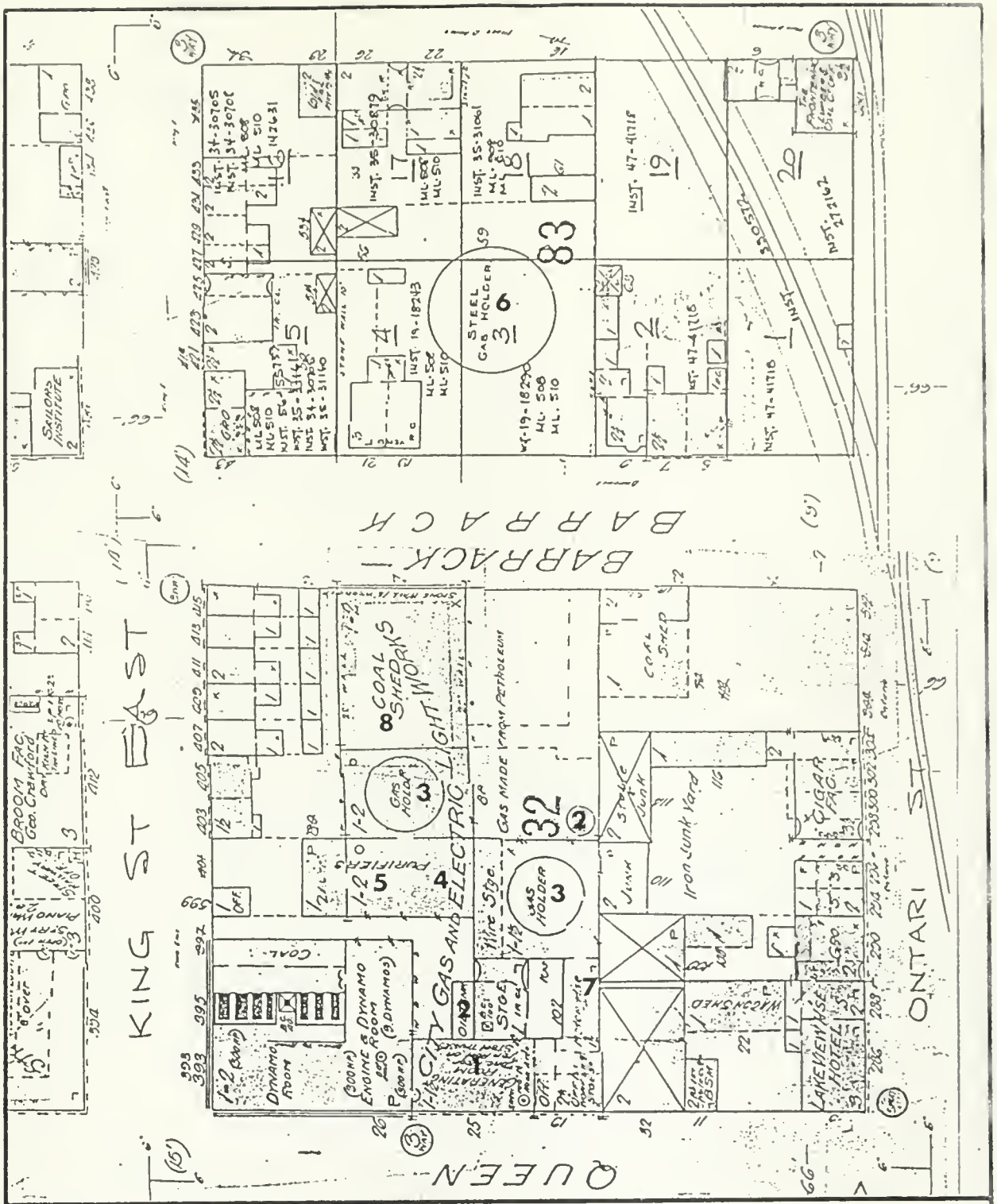
Figure 1.1


OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
QUEEN STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
KINGSTON POLICE BLDG
BARRACK STREET
TRANSIT GARAGE
MILLARD & LUNB
FRONTENAC VILLAGE
ANGLIN BAY
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
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FORMER GAS PLANT – KINGSTON
Site Plan of the Gas Plant Study Area
Figure 1.2

Historical maps for the gas plant site identify a number of potential waste storage locations which are of primary interest to this study. For the Kingston site, there were two different layouts. The first layout from historical maps of 1908 and 1911 is shown in Figure 1.3 and the second plan from 1924 is shown in Figure 1.4. The basic differences include changes in the locations of the relief gas holders and in the location of the purifier house. These changes in plant layout complicate the identification of waste storage containers because gas plant structures existed in different locations for different time periods. Therefore wastes may be found in several different locations on the plant site.

Normal operating procedures of gas plants usually result in waste material being located in the area of certain gas plant structures. For identification purposes, the following structures and their potential wastes are labelled by number on the two plant layouts (i.e., Figure 1.3 and 1.4):

1. Generator House - used to make gas in a retort. Waste may be found in sumps.
2. Oil tank - used for storage of oil (Bunker C) for water gas process or may have been used for tar storage;
3. Relief gas holding tank - used to store raw gas. Waste, consisting of tar sludges, may be found at the base of the tank and in its sump;
4. Condensor House - contained equipment to condense tars, oils and liquors from hot gases. Tar wells were usually proximate to this operation;
5. Purifier House - contains equipment to scrub raw gas to remove tars. May contain oxide box wastes. Tar wells and tar dehydrators are usually found beneath the purifier house;

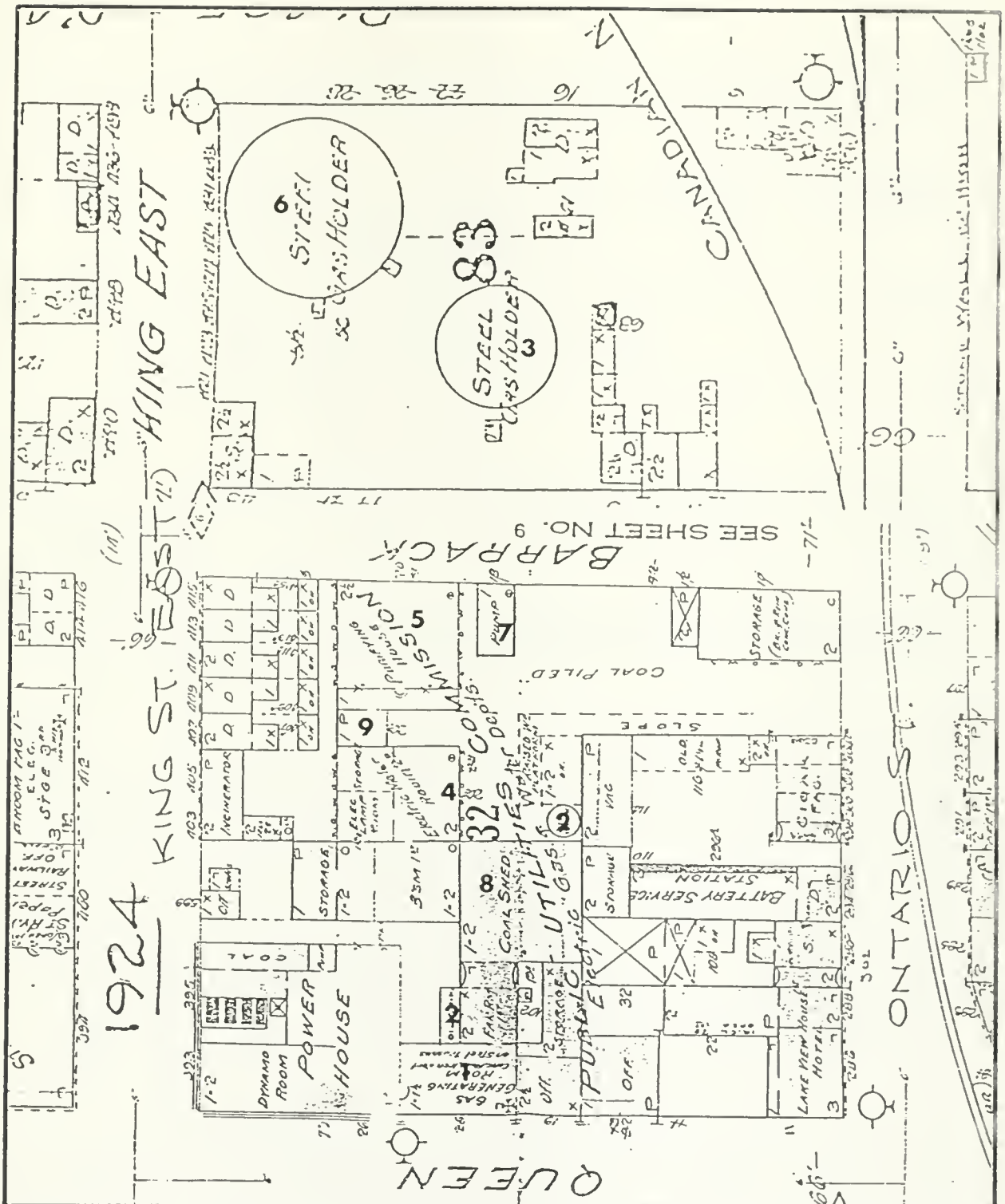


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1908 FIRE INSURANCE PLAN OF THE KINGSTON GAS PLANT (see text for description)

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FIGURE 1.3



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1924 FIRE INSURANCE PLAN OF THE KINGSTON GAS PLANT (see text for description)

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FIGURE 1.4

6. Main gas holding tank - used to store pure gas prior to distribution. May contain tar sludges on the base of the tank;
7. Meter House - used to regulate gas flow to consumers. No waste are associated with the meter house but tars may be found in the pipelines;
8. Coal Shed - used to store coal and coke. May contain spent coal, cinders and coal dust;
9. Oxide Room - storage of new or spent oxide (not found on 1908 map).

A detailed discussion of the actual wastes believed to be on-site, based on the results of field investigations, is found in Section 3.4.

1.4 GENERAL CHEMISTRY, ENVIRONMENTAL BEHAVIOUR AND HEALTH EFFECTS OF TAR WASTES

This section provides a brief discussion of the chemistry, environmental behaviour and health effects of tar wastes, to provide background information on the environmental fate and potential hazard posed by tar wastes generated by gas plants. Other types of wastes, such as spent oxide, ammonia liquor, cinders, slag and ash are also generated by gas plants but are considered to be of less importance from an environmental point of view as compared to tar wastes. The interested reader is directed to ERT (1984) for more detailed information on both tar and inorganic wastes from gas plants.

Coal tars and oil tars are all generated by the incomplete combustion of carbon based materials (i.e., coal, coke, oil) and the recovery and condensation of the gaseous products of such combustion. As such the coal and oil tars associated with coal gasification plants have generally similar physical and chemical characteristics and therefore similar environmental behaviour and health effects. The chemical and physical properties of a particular tar will be

determined from the type of raw materials, the temperature and type of combustion and the efficiency of condensing, exhausting and purifying operations.

The major organic chemicals associated with coal and oil tars that may pose an environmental concern are:

- Polynuclear Aromatic Hydrocarbons (PAH);
- Phenolics;
- Light Aromatics (e.g., benzene, toluene, xylenes).

These compounds are present in tars, sludges and liquors derived from coal. Table 1.1 shows the physical and chemical properties of typical coal tar constituents and the typical chemical composition of a coal tar. Oil and water gas tars are generally similar to coal tars but contain smaller amounts of nitrogenous PAH, benzene, toluene, anthracene and phenol and larger amounts of naphthalenes (Rogers, 1926).

Polynuclear aromatic hydrocarbons are compounds consisting of two or more fused benzene rings. The physical and chemical properties of PAH are dependent on the structure of individual compounds. The aqueous solubility and volatility of each compound decreases as the molecular weight of the compound increases. Therefore those compounds with a simple structure have higher solubilities and volatilities than those with a complicated structure. In general, PAH are strongly adsorbed and immobilized in soils and are also susceptible to biodegradation by microorganisms. Table 1.1 also lists the logarithm of the octanol-water partitioning coefficient, K_{ow}, which is a measure of the partitioning of coal tar constituents between the water and soil. Larger K_{ow} values indicate a greater affinity for adsorption. As a result of these properties, PAH tend to be relatively immobile in the environment. However, the fact that they occur in tars and that tars can migrate as immiscible, heavier-than-water or lighter-than-

water phases increases their mobility and potential environmental impact.

Light aromatics (i.e., monocyclic aromatic hydrocarbons, such as benzene, xylene and toluene) are moderately soluble, and biodegradable with high volatility and low sorption. They are expected to be relatively mobile in groundwater systems. However, the presence of these compounds will be largely determined by their volatility.

Phenolics (e.g., phenol, cresol and xylenol) are highly soluble with low sorption and high biodegradability and therefore are expected to be highly mobile in groundwater.

The environmental impact and risk associated with tars and tar wastes are derived from exposure and/or contact with polynuclear aromatic hydrocarbons and light aromatic hydrocarbons. The environmental impact from these substances results in adverse effects on human health and aquatic and terrestrial ecosystems. The most adverse effect associated with PAH and light aromatic hydrocarbons, is the increased incidence of cancer (ERT, 1984). Health effects associated with PAH are documented in the literature because of their ubiquitous presence in the environment. PAH are found in polluted air, tobacco smoke, cooking products, soots, tars, and oils. PAH are formed in a variety of hydrocarbon combustion processes routinely exposing most people to very low levels of PAH. In general, PAH are a large group of chemicals of which only a few have been suitably tested with respect to human health effects. The major routes of PAH adsorption are through inhalation and cutaneous exposure (Occupational Health Program, McMaster University, 1986).

Table 1.1 Physical and Chemical Properties of Typical Coal Tar Constituents

Constituent	Formula	Molecular Weight	Aqueous Solubility (mg/L)	Log K_{ow} [6]
PAH				
Naphthalene	$C_{10}H_8$	128.16	31.7[1]	3.37
Acenaphthylene	$C_{12}H_8$	152.21	3.9[5]	-
Acenaphthene	$C_{12}H_{10}$	154.21	3.93[1]	4.33[8]
Fluorene	$C_{13}H_{10}$	166.21	1.98[1]	4.12[5]
Anthracene	$C_{14}H_{10}$	178.22	0.073[1]	4.45
Phenanthrene	$C_{14}H_{10}$	178.22	1.29[1]	4.46
Fluoranthene	$C_{16}H_{10}$	202.26	0.26[1]	-
Pyrene	$C_{16}H_{10}$	202.24	0.135[1]	4.88[5]
1,2-Benzoanthracene	$C_{18}H_{12}$	228.28	0.014[1]	5.61[7]
Chrysene	$C_{18}H_{12}$	228.28	0.002[1]	5.61[7]
Benzo(a)pyrene	$C_{20}H_{12}$	252.30	0.0038[1]	6.04[7]
3,4-Benzofluoranthene	$C_{20}H_{10}$	252.32	0.0015[2]	6.7[8]
Benzo(ghi)perylene	$C_{22}H_{12}$	276.34	0.00026[1]	7.23
Indeno(1,2,3-cd)pyrene	$C_{22}H_{12}$	276.34	0.0002[2]	-
Dibenz(a,h)anthracene	$C_{22}H_{14}$	278.00	0.0005[4]	5.97[8]
Light Aromatics				
Benzene	C_6H_6	78.11	1780.[3]	2.13
Toluene	C_7H_8	92.13	538.[3]	2.69
Ethylbenzene	C_8H_{10}	106.16	159.[3]	3.15
Phenolics				
Phenol	C_6H_5OH	94.	82000.[6]	1.46
Meta-Cresol	$CH_3C_6H_5OH$	109.	23500.[6]	1.98

Notes:
[1] Data from Mackay and Shiu (1977)
[2] Data from NBS (1981)
[3] Data from McAuliffe (1963)
[4] Data from Pearlman et al. (1983)
[5] Data from Lyman et al. (1982)
[6] Data from Verschueren (1983)
[7] Data from USEPA (1980)
[8] Data from Versar (1979)

The carcinogenic activity of various PAH is given in Table 1.2 from ERT (1983). In general, the toxicity of PAH in various species increases as the molecular weight of the compound increases. This effect is tempered somewhat by differences in solubility in that heavier compounds are less soluble, and therefore, less mobile in aqueous environments. PAH are noted to bioaccumulate in animal tissue of aquatic organisms and also are accumulated by adsorption in plants. The adsorption tends to be onto root surfaces as opposed to into the plant structure and, therefore, does not accumulate in the plant itself.

Single ringed, light aromatic hydrocarbons found in coal, and oil tars generally consist of the toxic compounds benzene, toluene, xylene and ethylbenzene. Of these compounds, benzene is the most toxic because of its carcinogenic health effects (USEPA, 1980a). The common method of human exposure is by inhalation due to the volatile nature of the light aromatics.

Chronic exposure to benzene has the most serious health effects of the light aromatics because of its increased risk for the development of leukemia (ERT, 1984). All of the light aromatic hydrocarbons affect the central nervous system with acute symptoms including headache, dizziness, fatigue, nausea, unconsciousness and coma.

In aquatic ecosystems, the light aromatic hydrocarbons are moderately toxic to fish and lower species. Toxic levels of benzene, toluene, and xylene generally range from 1 to 100's of $mg \cdot L^{-1}$. For example, rainbow trout were found to have an LC-50 (lethal concentration for 50 percent of the population) of 5.3 $mg \cdot L^{-1}$ for benzene (USEPA, 1980a).

Table 1.2 Carcinogenic Activity of Some Unsubstituted Polycyclic Aromatic Hydrocarbons (ERT, 1983)

Compound	Activity
Acenaphthylene	-
Anthanthrene	-
Anthracene	-
Benzo[a]naphthacene	-
Benzo[a]pyrene	+ (c,d)
Benzo[a]fluorene	-
Benzo[b]chrysene	-
Benzo[b]fluoranthene	+ (c,d)
Benzo[b]fluorene	-
Benzo[c]chrysene	+
Benzo[c]fluorene	-
Benzo[c]phenanthrene	-
Benzo[e]pyrene	-
Benzo[g]chrysene	-
Benzo[ghi]fluoranthene	-
Benzo[ghi]perylene	-
Benzo[j]fluoranthene	+ (c)
Benzo[k]fluoranthene	-
Benz[a]anthracene	+ (c,d)
Chrysene	+ (c)
Coronene	-
Dibenzo[a,e]pyrene	+ (c,d)
Dibenzo[a,h]pyrene	+ (c,d)
Dibenzo[a,i]pyrene	+ (c,d)
Dibenzo[a,j]naphthacene	-
Dibenzo[a,l]pyrene	-
Dibenzo[b,g]phenanthrene	-
Dibenzo[b,k]chrysene	-
Dibenzo[de,qr]naphthacene	-
Dibenzo[e,l]pyrene	-
Dibenz[a,c]anthracene	+
Dibenz[a,h]anthracene	+ (c,d)
Dibenz[a,j]anthracene	+
Fluoranthene	-
Fluorene	-
Hexacene	-
Indeno[1,2,3-cd]pyrene	+ (c,d)
Naphthacene	-
Naphthalene	-
Naphtho[2,3-b]pyrene	+
Pentacene	-
Pentaphene	-
Perylene	-
Phenanthrene	-
Picene	-
Pyrene	-
Tribenzo[ael]pyrene	+
Triphenylene	-

[a]Data from Shear, 1938, 1941; Arcos and Argus, 1974; Dipple, 1976; Santodonato et al., 1981

[b]Symbols: + complete carcinogen by either skin painting, subcutaneous injection, intramuscular injection, intravenous injection, intraperitoneal injection, intratracheal instillation, oral administration to mammals
- negative in animal bioassay

[c]Compounds classified as "having substantial evidence of carcinogenicity" by the U.S. EPA Carcinogen Assessment Group (U.S. EPA, 1980b). The CAG list also includes two alkylated PAH (7, 12-dimethylbenz(a)anthracene and 3-methylcholanthrene), as well as "coal tar and soot", "coke oven emissions (polycyclic organic matter)" and "creosote".

[d]Compounds classified as showing "sufficient evidence" of carcinogenicity for animal carcinogens by the International Agency for Research on Cancer.

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A recent Ontario Ministry of Labour sponsored study, (Occupational Health Program, McMaster University, 1986) provides a comprehensive review of the available scientific evidence relating to health effects of coal tar and other substances which contain polynuclear aromatic hydrocarbons. This study concludes that there is sufficient evidence concerning human carcinogenic potential of coal tar products in the literature to warrant stringent control of workplace exposures. This study recommends an interim standard for occupational exposure to volatiles of coal tar products at 0.05 mg/m^3 (cyclohexane soluble extract) time weighted over an 8 hour working day and zero dermal exposure.

2. FIELD INVESTIGATIONS

2.1 PHASE 1 - PRELIMINARY INVESTIGATIONS

2.1.1 Historical Review

Prior to the start of any field work, a review of existing information and a site visit was completed. The review included INTERA's Inventory report and associated historical site maps and assessment methods. Most of this information was provided to the Ministry as part of the Inventory study and was applied to the review portion of this study. The review of historical site maps included the maps listed in the reference section of this report.

INTERA also obtained and reviewed air photographs, both historical and present, for the site. The list of air photos is given in the reference section of this report. The air photos were compared to the historical maps to confirm locations of gas plant structures.

The historical review also included the collection and review of any available geotechnical or engineering information regarding soils, foundations, buildings, utility lines or bridges. Borehole logs, test pits, and excavation reports for the police station and city sewer construction are examples of this type of information. The complete list of geotechnical reports is given in the reference section of this report.

The purpose of the review of existing information was to determine the location of potential waste storage locations. From the historical maps and site plans, gas plant structures, such as the condensor house, generator house, gas relief tanks, gas holding tanks, and tar pipelines were identified and placed on a present-day site plan as accurately as possible. With the waste storage locations identified relative to present day structures, it was possible to define

appropriate surface investigations such as sampling and drilling locations and survey lines. The historical review provides the information used in site description in Section 1.3. The interpretation of the historical data is provided in Section 3.1.

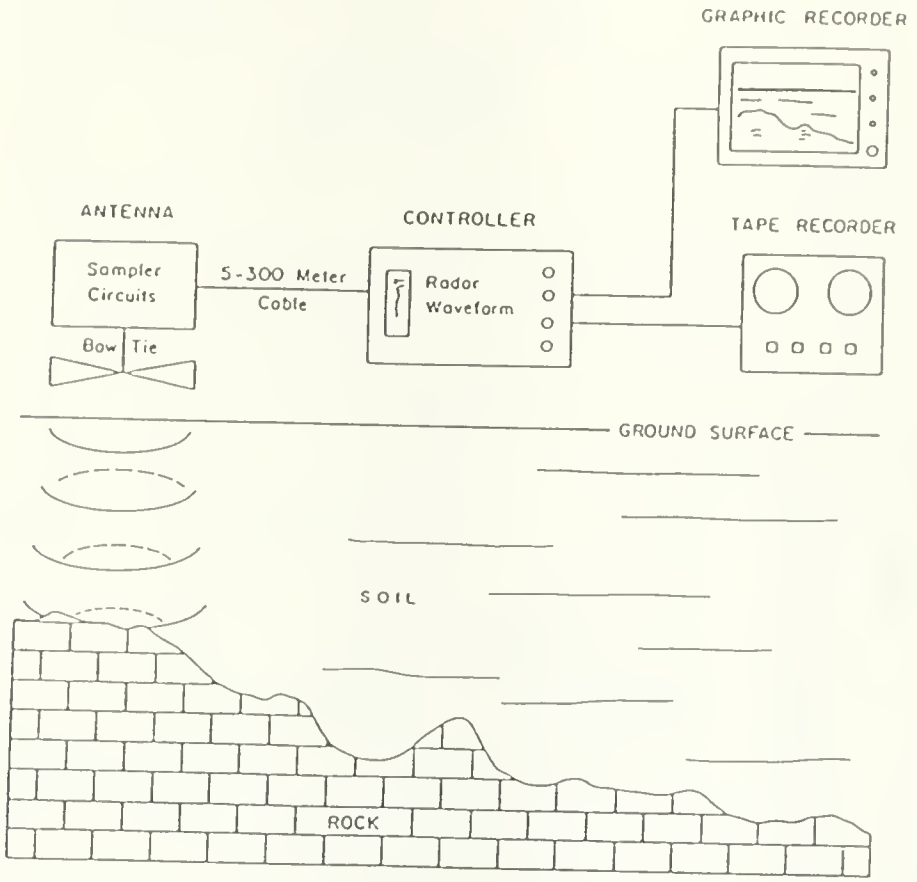
In addition, as part of the review, utility lines such as storm and sanitary sewers, gas lines, building sumps, water and electrical lines etc. were identified and placed on the site map. Prior to any field work, all utility lines were also located in the field.

2.1.2 Ground Probing Radar

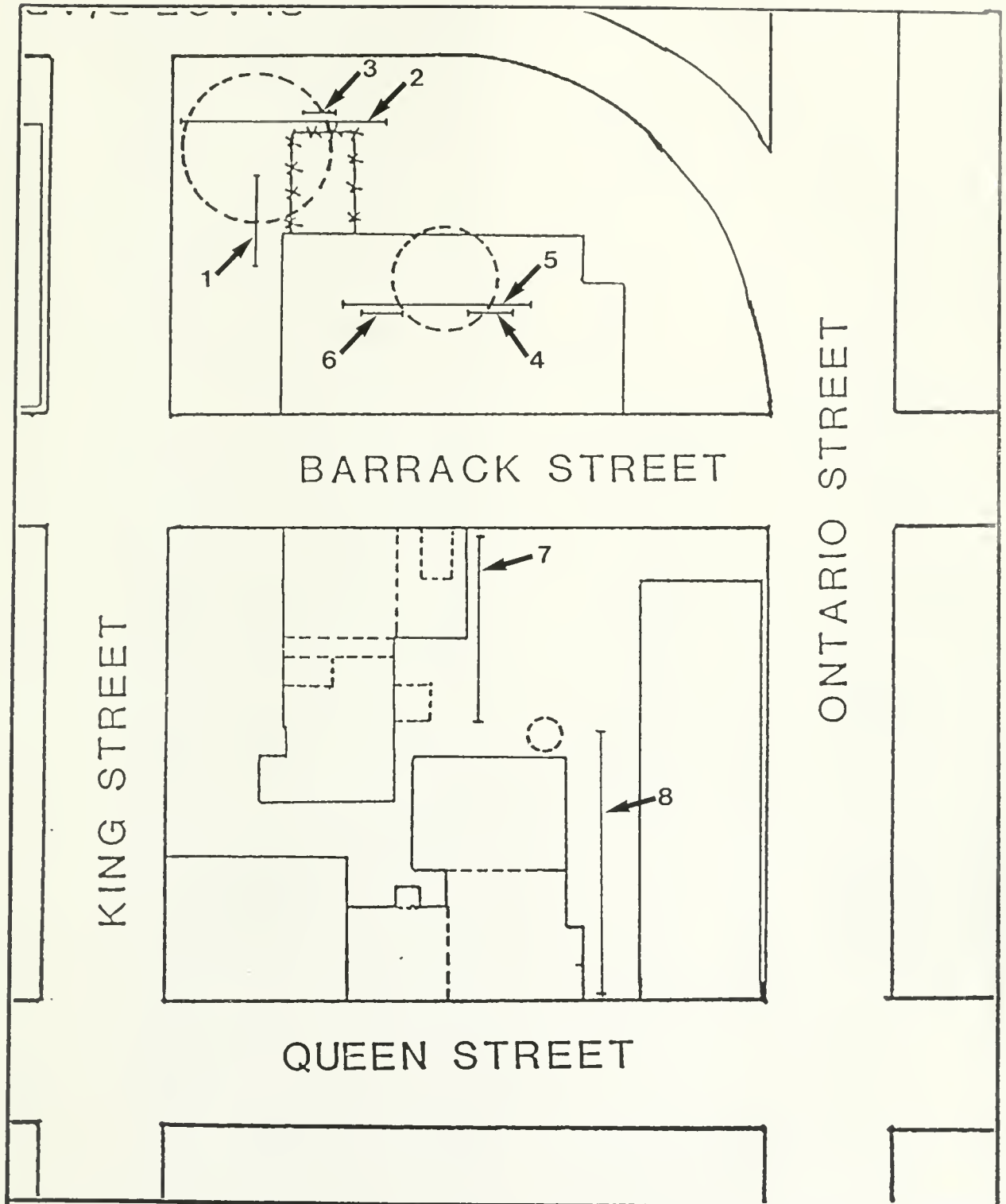
Ground probing radar (GPR) was used as a geophysical method to assist in the identification of buried waste storage locations. The GPR is a reflection technique using high frequency radio waves which are bounced off subsurface features. The radar equipment is shown schematically in Figure 2.1. The radar survey provides a continuous cross-sectional picture or profile of the subsurface which is particularly effective in identifying hydrogeologic conditions and buried man-made structures.

The GPR survey was completed by Canpolar Consultants Ltd. of Toronto, a subsidiary of INTERA Technologies Ltd. Canpolar's GPR system includes a 120 MH_Z frequency antenna, a Hewett-Packard control unit for processing, a graphic recorder and a magnetic tape recorder.

The GPR survey consisted of the survey lines indicated in Figure 2.2. The survey lines were situated in areas of easy access and in areas of suspected buried gas plant structures. An example of the ground penetrating radar survey is given in Figure 2.3. The complete survey results are given in Appendix B.



Drawn by	Date	Schematic of a Ground Penetrating Radar System
Checked by	Date	
Revisions	Date	
INTERA Technologies		Figure 2.1



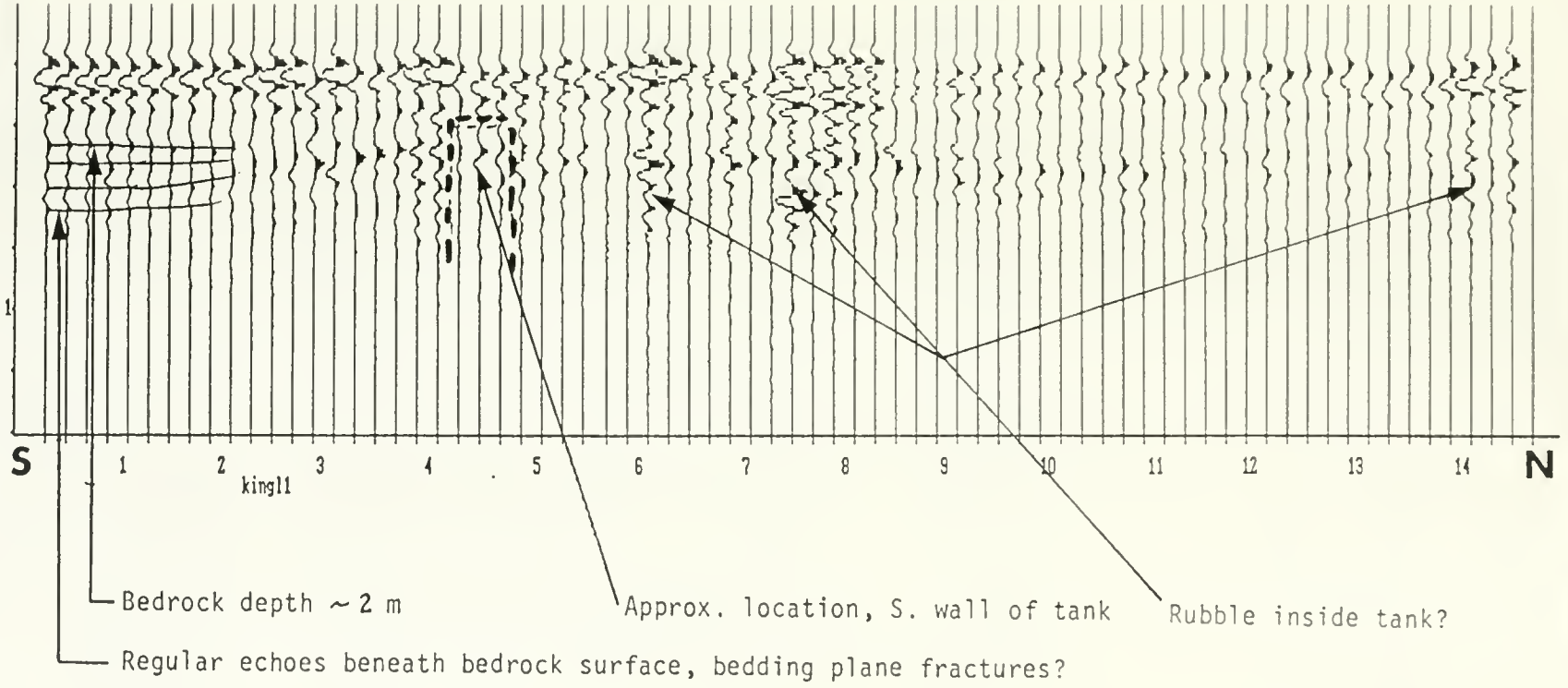
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Checked by	Date
Revisions	Date

SITE MAP SHOWING LOCATION OF GROUND PENETRATING RADAR SURVEY LINES

INTERA Technologies

SCALE 1cm = 10.2m

FIGURE 2.2



Drawn by	Date
Checked by	Date
Revisions	Date

Kingston, Line No. 1
Ground probing radar survey

INTERA Technologies

FIGURE 2.3

The radar survey was most useful to identify the sides of the main and relief gas holder in the Barrack - Place D'Armes block, the bedrock surface and the water table. The use of ground probing radar was hampered by the presence of buildings and parking lots covering the site. When running the survey in the bus garage, for example, reflections off of the walls and ceiling of the building caused considerable noise to the receiver which complicated the interpretation of the results.

2.1.3 Soil Sampling

Soil sampling using a hand auger was conducted on the Kingston site to provide visual and olfactory evidence of gas plant wastes in the shallow surface materials. Soil sampling provided a fast and inexpensive reconnaissance tool in the site investigations.

Soil sampling was conducted using a 32 mm hand auger and sampler tube to a maximum depth of about 1.0 m. The samples provided an indication of the type of soils found at the surface and were visually inspected for evidence of gas plant wastes (i.e., tar, cinders, ash, oxide box wastes, etc.). Odours, such as the distinctive coal tar smell which is detectable to levels of about 1 ppb of total PAH were noted if present. In addition to visual and olfactory inspections, the soil samples were surveyed for organic vapours using a photo-ionization detector organic vapour meter (OVM) to provide a more quantitative indication of coal tar wastes. If the visual and olfactory evidence indicated coal tar contamination, the soil samples were retained and were submitted, if necessary, for analysis as part of the Phase 2 studies.

At the Kingston site, the majority of the property is covered by buildings, parking lots or pavement. To obtain soil samples, a 3.8 cm diameter hole was drilled using an electric power drill through the floors of buildings or pavement. Soil samples using the hand auger were collected through the drilled holes.

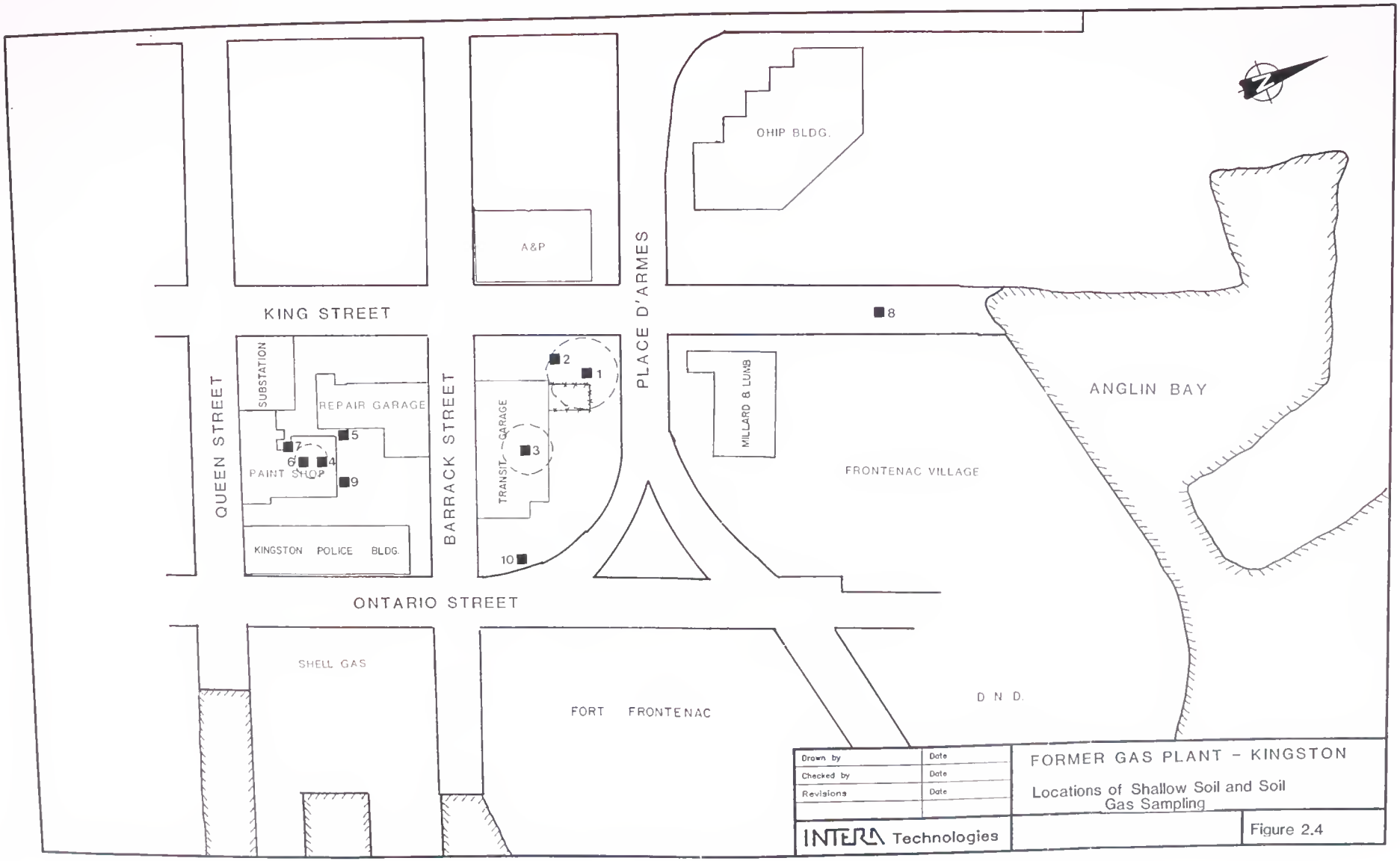
The locations selected for soil and soil gas sampling were based on the results of the ground probing radar survey, the historical review of waste container locations and the locations of buried utility lines which may act as conduits for waste migration. Soil and soil gas sample locations are presented in Figure 2.4.

The soil sampling did not detect evidence of coal tar waste in any of the shallow holes. For the most part, only fill material was found in the 1.0 metre deep holes. The fill material was typically sand, gravel or clay but gas plant wastes such as coal, cinders and ash were found at several locations (Hole No. 5, 7 and 9). Because evidence of coal tar was not found in any of the shallow holes, no soil samples were submitted as part of this study.

At the Kingston site, an attempt was made to collect soil samples in the area of all waste storage locations. Numerous boreholes, 16 in total, were attempted in the shallow soil sampling program but only 9 were completed to 1.0 metre depth. Most of the unsuccessful holes met refusal on foundations or boulders which could not be penetrated with the electric drill.

2.1.4 Soil Gas Sampling

In conjunction with the soil sampling program, soil gas sampling was also performed. Gas sampling using a Thermo Environmental Instrument Model 590 organic vapour meter (OVM) was used to identify light aromatic compounds such as benzene, toluene or xylene which volatilize from coal tar. The organic vapour meter was used as a screening tool to provide a general indication of the extent of hydrocarbon contamination. The organic vapour meter can provide a detection limit of about 0.1 ppm total organic vapour.


OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
QUEEN STREET
BARRACK STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
TRANSIT GARAGE
KINGSTON POLICE BLDG.
MILLARD & LUNB
ANGLIN BAY
FRONTENAC VILLAGE
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D N D.
1
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Date
Revisions
Date
INTERA Technologies
FORMER GAS PLANT - KINGSTON
Locations of Shallow Soil and Soil Gas Sampling
Figure 2.4

Soil gas samples were collected from the same auger holes used to collect the soil samples. After collection of the soil sample, a gas sampling probe was placed to the bottom of the auger hole and driven by hand a depth of 1.0 m (i.e., 2.0 m below surface) or to refusal. Soil gas samples were collected from the probe by attaching the air pump of the organic vapour meter to the top of the probe and withdrawing a volume of soil gas.

The soil gas was run continually through the OVM for a period of 2 - 3 minutes to provide a total organic vapour concentration in ppm. The soil gas concentration was compared to the ambient air quality which was generally in the range of 0.5 to 2.0 ppm to provide an indication of contaminated soil conditions. In uncontaminated conditions, the soil gas concentration was typically less than the ambient air concentration. In most cases, the open hole soil gas was also measured after the soil gas probe was removed.

Soil gas sampling was undertaken in the same locations as the soil samples indicated in Figure 2.4.

The soil gas sampling results are given in Table 2.1. Organic vapour concentrations significantly above background were found in test holes 4, 6, 7 and 9. Obvious coal tar contamination was also found in test holes 7 and 9 on the end of the soil gas probe when it was removed. In test holes 4 and 6 located inside the paint garage the interpretation of high organic vapours in the holes is complicated by the fact that solvents are used in the garage.

Table 2.1 Kingston Soil Gas Concentrations

Hole No.	Background (ppm)	Gas Probe (ppm)	Open Hole (ppm)
1	1.2	1.0	
2	1.5	0.9	
3	1.5	1.0	
4	1.5	1.5	25 - 100
5	1.2	0.9	
6	1.3	2.4	
7	1.2	6 - 7	
8	0.8	0.8	
9	1.2	2.0	16 - 20
10	1.2	1.2	1.2

2.2 PHASE 2 DRILLING AND SAMPLING PROGRAM

The objectives of the Phase 2 Drilling and Sampling Program were to determine the contents of any identified storage vessels remaining underground and to determine the presence or absence of any contamination in the soils and groundwater adjacent to the locations of former storage vessels. To achieve these objectives, the Phase 2 program was divided into a number of subtasks as follows:

- Air monitoring;
- Health and safety;
- Soil sampling;
- Well installation and sampling;
- Utility line sampling.

The following sections outline the details of each of these subtasks.

2.2.1 Air Monitoring

Air monitoring was required as part of the site investigations in order to monitor and control emissions resulting from the exposure of waste materials and to assist in implementing the health and safety program. Air monitoring at the Kingston site was implemented on a real-time basis using a hand held organic vapour meter (OVM) with an attached gas chromatograph. The use of real-time measurements allowed for the immediate implementation of emission control measures when the OVM indicated hazardous conditions. INTERA's portable gas chromatograph allowed for a more detailed analysis of the type and concentration of the emission if a hazardous condition existed.

Prior to the start of any field work, measurements were taken three times a day (8:00, 12:00 and 18:00 hours) to establish the background air quality. These measurements were completed using the

OVM and the portable GC to provide complete quantification of the background air quality. Background air quality was typically 0.5 to 2.0 ppm total organic vapour depending on the location. In locations with automobile traffic the organic vapour concentration was typically at the higher end of the range. Using the gas chromatograph, a wide variety of organic chemicals were detected in the ambient air but all were at trace levels (i.e., less than 0.1 ppm). Air monitoring using the OVM was conducted continuously in the downwind direction during all field work where there existed the potential for exposure of waste or contaminated material (i.e., during soil sampling and drilling).

Monitoring was also completed periodically (typically at 1 hour intervals) during the drilling activities in order to detect and monitor possibly hazardous conditions. Monitoring was conducted at the top of the augers, in the driller's breathing space, and at the mud discharge line (during rock coring only). Although the monitoring occasionally indicated high readings (i.e., 10 - 25 ppm) at the top of the augers and/or the mud line during the drilling of contaminated material, the ambient air quality at the perimeter of the work area was not impacted during the field activities.

2.2.2 Health and Safety Plan

The health and safety plan (HSP) for all field work conducted on the Kingston site followed the Ministry of Labour's "Occupational Health Protocols for Workers Exposed to Waste from Decommissioned Coal Gasification Plant Sites".

The health and safety procedures were inspected during the drilling activities by the Ministry of Labour and were found to be compliant with the protocols.

The following paragraphs outline special health and safety procedures used during the field activities.

2.2.2.1 Air Monitoring. The monitoring program for air quality described in Section 2.2.1 showed that the field activities did not significantly impact the ambient air quality beyond the perimeter of the work area. Total organic vapour concentrations equal to the background concentrations were always detected in the downwind direction. Elevated organic vapour readings were detected in the augers and at the mud tank but background concentrations were found in the workers breathing space. As a precaution, half-face respirators with organic vapour/acid gas cartridges were worn with other safety equipment whenever hazardous materials were encountered.

2.2.2.2 Equipment Decontamination. In Kingston, all equipment exposed to contaminated materials was decontaminated using the high pressure, steam wash unit located in the PUC's bus wash station. Washing was completed using a steam wash, detergent wash and water wash cycle. All wash waters were flushed to the sanitary sewer.

2.2.2.3 Waste Material Handling. Any solid or liquid material that was considered to be hazardous was stored on-site in 45 gallon drums with lids. The hazardous material was removed for disposal under an MOE emergency generator registration by O.E. MacDougall, a licensed waste hauler. The drilling wash water from the rock coring operation was disposed to the sanitary trunk sewer with the approval of the City of Kingston Works Department and MOE.

2.2.3 Drilling Locations

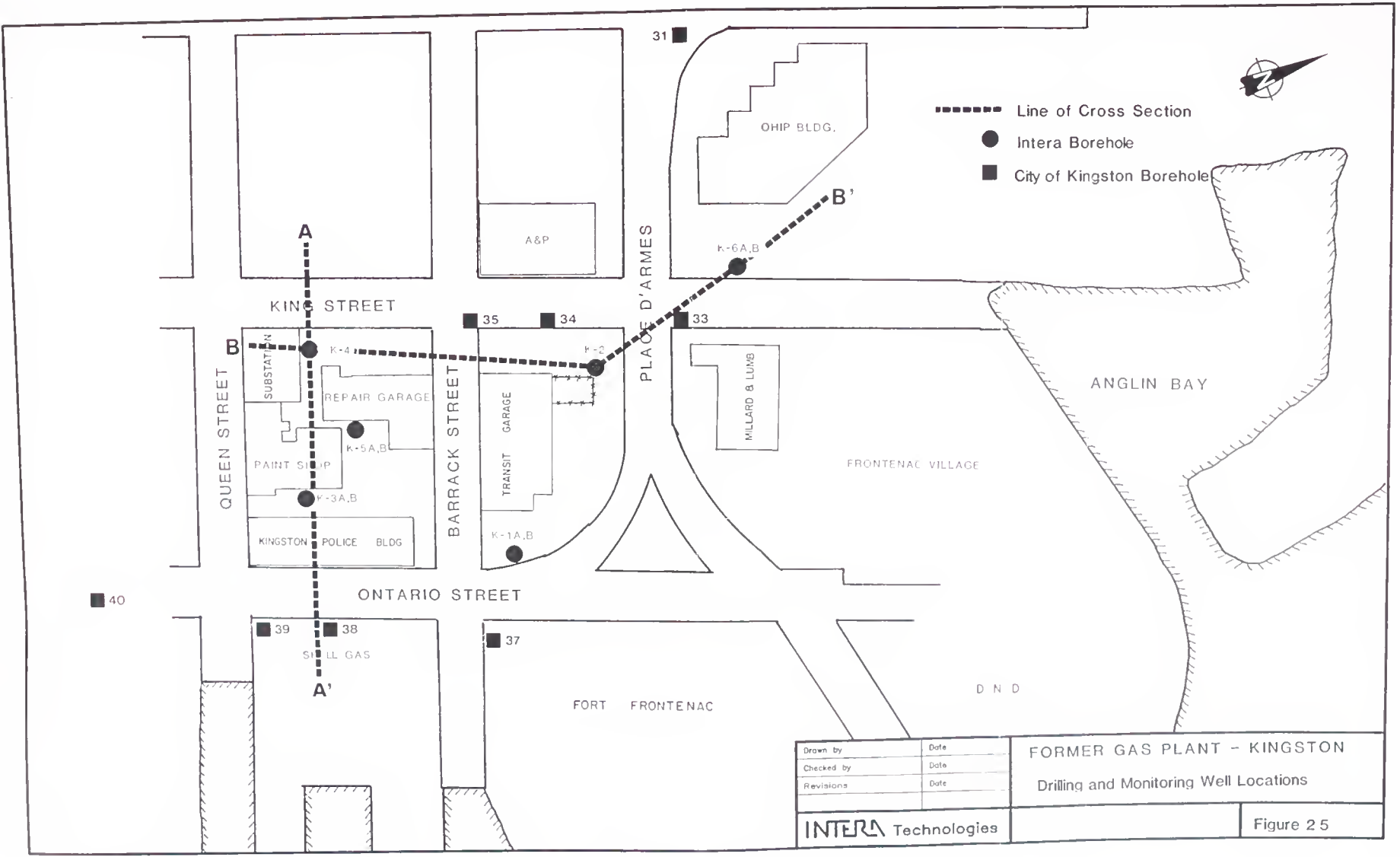
On the Kingston site the locations of the test boreholes were selected to assess former gas plant structures identified as part of Phase 1 investigations and to assess subsurface conditions at the boundaries of the site. Four boreholes were located at the corners of the former gas plant site and one borehole was located at the center of the Queen-Barrack block. These boreholes were also situated as much as

possible in the area of suspected gas plant structures. One additional borehole was placed off-site in the area of the north end of King Street. The borehole locations are given in Figure 2.5.

2.2.4 Drilling and Soil Sampling

Drilling was completed using a truck mounted soil-auger drill rig (CME 75), hollow stem augers, a continuous soil sampler or split spoon sampler and rock coring equipment. Drilling equipment was supplied and operated by Environmental Systems of Ingersoll. The continuous soil sampler or split spoon was advanced in front of the lead auger and collected a soil core for soil identification and logging. Each auger borehole was advanced to the bedrock surface which in most cases was at depths less than 2.5 m. The boreholes were advanced into the bedrock using a HQ rock coring technique which left a borehole of about 100 mm diameter. The bedrock was cored continuously to depths of up to 10 m below surface.

Each soil sample or rock core was logged for stratigraphy noting soil type, grain size, texture and structure. In addition to logging for stratigraphy, each soil sample was examined for visual or olfactory evidence of contamination. An organic vapour meter was used to monitor each sample for coal tar wastes. The interpretation of odours and organic vapours was complicated in the rock coring technique because as soon as a contaminated zone was intersected the drill water would take on a coal tar odour. The drill water would then add odours and vapours to the core regardless of whether or not coal tar was present. After logging, each soil sample or rock core was bagged, labelled and stored for future reference. All information regarding soil stratigraphy, structure, evidence of odours or waste etc. was identified on a borehole log. The borehole logs are contained in Appendix C.


Line of Cross Section
Intera Borehole
City of Kingston Borehole
OHIP BLDG.
A&P
KING STREET
QUEEN STREET
BARRACK STREET
PLACE D'ARMES
SUBSTATION
REPAIR GARAGE
PAINT SHOP
TRANSIT GARAGE
KINGSTON POLICE BLDG
MILLARD & LUMB
ANGLIN BAY
FRONTENAC VILLAGE
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D N D
A
A'
B
B'
K-1A,B
K-2
K-3A,B
K-4
K-5A,B
K-6A,B
31
33
34
35
37
38
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Checked by
Revisions
Date
FORMER GAS PLANT - KINGSTON
Drilling and Monitoring Well Locations
INTERA Technologies
Figure 2 5

2.2.5 Surface Water and Sediment Samples

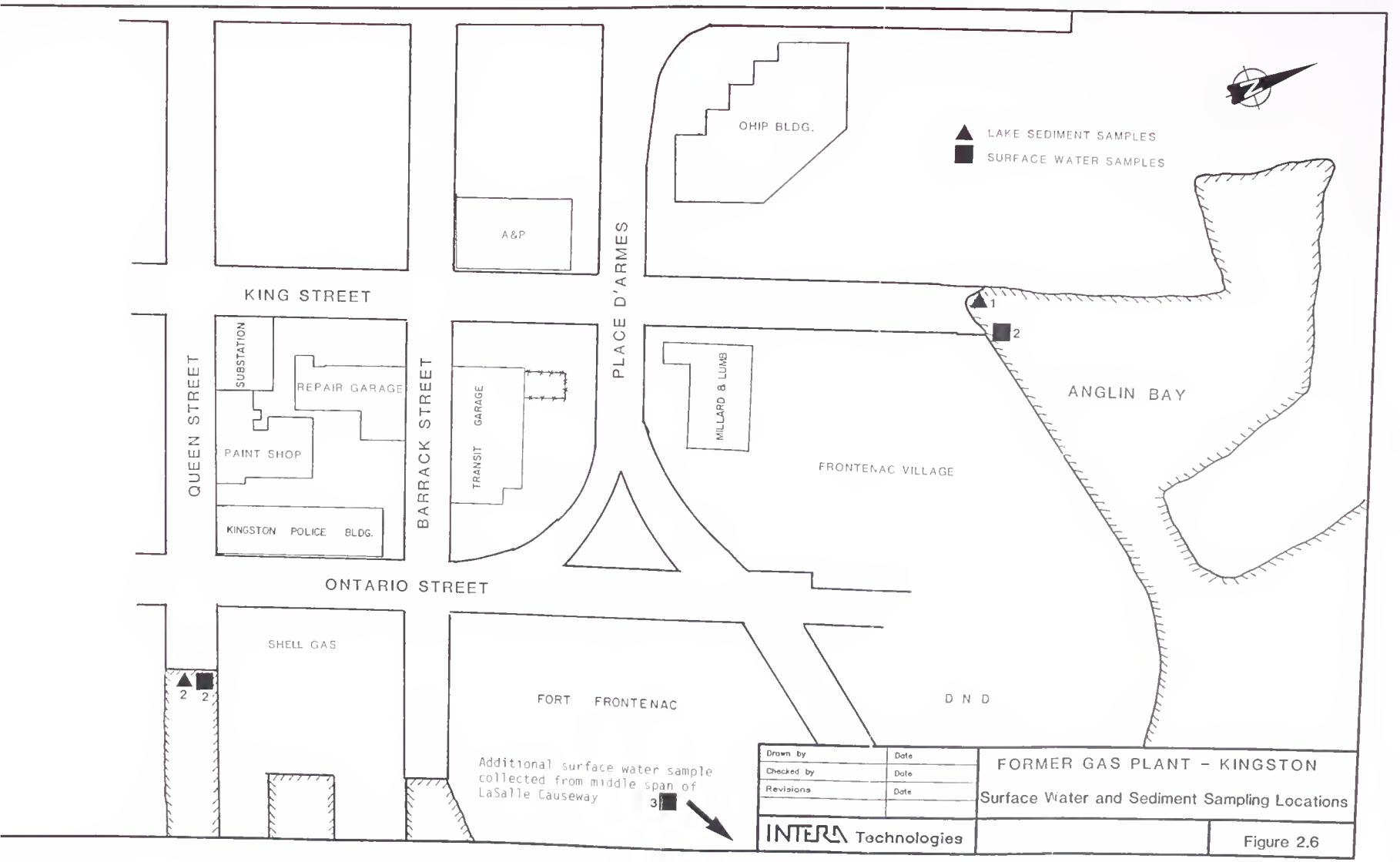
Surface water samples were collected from Anglin Bay at the end of King St. and from Lake Ontario at the end of Queen St. A background sample was collected from the bridge of the LaSalle Causeway. Sediment samples were collected from the bank of the Great Cataraqui River at Anglin Bay and at Kingston Harbour, to define the extent and type, if any, of tar wastes in the sediments. The sampling locations are identified in Figure 2.6 and listed as follows:

1. Bank of Anglin Bay at end of King Street East;
2. Kingston Harbour at end of Queen Street;
3. Bridge of the Lasalle Causeway.

These locations provide a preliminary indication to determine if contamination from the gas plant is reaching the Great Cataraqui River, St. Lawrence River (east of mouth of Great Cataraqui River) or Lake Ontario (west of mouth of Great Cataraqui River).

Surface water samples were collected by simply immersing the sample bottle. The surface water samples were analyzed for major ions (Na, K, Ca, Mg, SO_4, Cl, Si, NO_3+NO_2, NH_3, Fe, Mg, Cu, Zn), conductivity, pH, TDS, TOC, turbidity, and colour as well as PAH. The surface water quality results are given in Appendix D and the interpretation of the results are given in Section 3.

Sediment samples were collected using a hand driven soil sampler. This sampler type allowed for an assessment of waste material of the shallow sediment only and is not representative of deeper sediment. Each sample was described in terms of composition then examined for visual and olfactory evidence of tar. The samples were placed into glass sample jars for storage. The sediment samples were submitted for chemical analysis for the following compounds:


OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
QUEEN STREET
BARRACK STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
KINGSTON POLICE BLDG.
TRANSIT GARAGE
MILLARD & LUMB
FRONTENAC VILLAGE
ANGLIN BAY
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D N D
LAKE SEDIMENT SAMPLES
SURFACE WATER SAMPLES
1
2
2
2
3
Additional surface water sample collected from middle span of LaSalle Causeway
Drawn by
Date
Checked by
Date
Revisions
Date
INTERA Technologies
FORMER GAS PLANT - KINGSTON
Surface Water and Sediment Sampling Locations
Figure 2.6

Trace metals,
Cyanide,
Volatile Organics (including benzene, toluene, xylene),
Polyaromatic hydrocarbons (17-EPA Priority PAHs, including naphthalene, benzo(a)pyrene).

The results of the sediment analyses are found in Appendix D and described in Section 3.

2.2.6 Monitoring Well Installation and Sampling

After the drilling of test holes in the soil sampling program, the holes were completed as temporary monitoring wells for the purpose of providing water level measurements and water quality samples. The well locations are the same as the drilling soil sampling locations given in Figure 2.5. Each of the boreholes was completed as a monitoring well with either one or two screened intervals placed in each hole. The well installation details are given in Table 2.2 and as constructed drawings are given in Appendix C. In some boreholes two well screens were set at different levels to provide two monitoring points. In these locations, one 1.5 m length, 32 mm diameter PVC well screen and flush threaded PVC pipe was placed at the bottom of the borehole and sand packed into place using a silica sand. The second PVC well screen (3.0 m length and 32 mm diameter) and pipe was placed to straddle the water table and was separated from the lower well screen by a bentonite plug. The upper screen was sand packed along its length and the remainder of the borehole filled with bentonite to ground surface. The lower well screen was designated the "A" well while the upper was designated the "B" well. A protective casing with a locking cap was placed around the standpipe at surface. All monitoring well equipment was washed with tap water, methanol and distilled water by the manufacturer prior to use.

TABLE 2.2 FORMER GAS PLANT STUDY KINGSTON, ONTARIO
SUMMARY OF WELL INSTALLATION DETAILS

WELL NUMBER	TOP OF CASING (mASL)	GROUND SURFACE (mASL)	BOT. OF HOLE (mASL)	TOP OF SANDPACK (mASL)	BOT. OF SANDPACK (mASL)	INTERVAL LENGTH (m)
K-1A	79.42	78.67	67.77	70.26	67.77	2.49
K-1B	79.42	78.67	67.77	76.69	72.12	4.57
K-2	80.88	80.12	72.40	79.21	72.40	6.81
K-3A	78.86	78.17	67.22	69.86	67.22	2.64
K-3B	78.86	78.17	67.22	76.04	71.41	4.63
K-4	80.67	80.08	75.71	78.25	76.09	2.16
K-5A	80.60	79.89	69.04	71.41	69.04	2.37
K-5B	80.60	79.89	69.04	77.58	73.16	4.42
K-6A	77.94	77.38	66.48	68.90	66.48	2.42
K-6B	77.94	77.38	66.48	76.16	71.89	4.27

Where a single well screen was placed in each borehole, the screen was set at the bottom of the borehole and completed as for the upper screen in the double installation.

After installation, each well was developed by surging using a surge block and purging of three well volumes using a Waterra hand pump. In some cases, where the well was known to contain free product, a pump was dedicated to the well. The purge water was contained on-site in 45 gallon drums and disposed to the sanitary trunk sewer with the approval of the City of Kingston Works Department and MOE.

Each monitoring well was slug tested at least three times where possible to determine the average hydraulic conductivity of the well interval. The slug test method consisted of removing a volume of water from the well using the Waterra pump as a bailer and monitoring the recovery of the water level. The results of the slug testing are presented in Table 2.3 and discussed in Section 3.

Each monitoring well was surveyed by an Ontario Land Surveyor to determine its elevation with respect to mean sea level.

Prior to sampling, each well was purged of another three well volumes or purged dry. Groundwater samples were collected from the well as it recovered using a 6 mm diameter polyethylene tube and a peristaltic pump.

All sampling equipment was washed with tap water, methanol, and distilled water prior to use to prevent cross-contamination. The 6 mm diameter sampling tube and peristaltic pump tube were used once and disposed.

Samples were analyzed for the parameters given in Table 2.4. PH, electrical conductance and temperature were measured on each sample in the field.

TABLE 2.3 SUMMARY OF HYDRAULIC CONDUCTIVITY TEST RESULTS FOR THE FORMER KINGSTON GAS PLANT

WELL NUMBER	INTERVAL LENGTH (m)	WELL RADIUS (m)	HYDRAULIC CONDUCT (m/s)	TRANS-MISSIVITY (m2/s)	ANALYSIS TYPE
K-1A	2.51	.048	2.9E-08	7.3E-08	H
K-1B	2.92	.048	8.4E-07	2.5E-06	H
K-2	6.81	.152	>1.0 E-04	NA	
K-3A	2.64	.048	1.5E-06	4.0E-06	C
K-3B	4.62	.048	3.6E-07	1.7E-06	R
K-4	2.16	.048	NA	NA	
K-5A	2.37	.048	2.6E-09	6.2E-09	H
K-5B	3.67	.048	1.1E-06	4.0E-06	C,H
K-6A	2.41	.048	1.5E-06	3.6E-06	C,H
K-6B	4.27	.152	1.6E-07	6.8E-07	H

C = COOPER H = HVORSLEV
R = RECOVERY NA = NOT ANALYSABLE

Table 2.4 Hydrochemistry Parameters

pH

Calcium
Magnesium
Sodium
Potassium

Trace Metals:

Alkalinity
Bicarbonate
Sulphate
Sulphide
Chloride
Cyanide
Ammonium
TKN
COD
TOC
Phenols

Volatiles:

Benzene
Toluene
Xylenes

PAHs:

17-EPA Priority PAHs including:
Benzo(a)pyrene
Naphthalene

The following parameters required special preservation techniques:

- Trace metals - HNO_3;
- Cyanide - 50% NaOH;
- Phenols - H_3PO_4 to pH 4 and $CuSO_4$.

All samples were packed on ice until delivery to the laboratory. Volatile organic samples were collected in amber glass septum vials and filled without air bubbles. PAH and cyanide samples were also collected in amber glass bottles.

Six groundwater samples from monitoring wells K1A, K1B, K2, K3A, K5A and K6A were submitted for analysis. Groundwater samples collected for volatiles and PAH were sent to Novalab, in Lachine, Québec while all other samples were sent to Bondar-Clegg Laboratories, Ottawa. The complete groundwater analytical results are given in Appendix E. The interpretation of the results is given in Section 3.

After sampling a water level monitoring program was implemented to determine the static piezometric level for each well. Water levels from all wells were collected on the same day. Water level elevations were reported with respect to mean sea level. The results of the water level monitoring are given in Table 2.5 and are discussed in Section 3.

2.2.7 Utility Line and Sump Inspections

Utility lines and building sumps in the area of the gas plant were inspected for evidence of coal tar contamination. The utility lines, the storm and sanitary sewers were of primary concern because these lines receive runoff water and are typically the deepest of all utility lines. Each of the storm and sanitary sewer manholes indicated

TABLE 2.5
FORMER GAS PLANT SITE
PROJECT NO. H88-026

WATER LEVEL RECORD SHEET
CITY OF KINGSTON
LAST UPDATE: 6 MAY 88

Well ID	Location Description	Well Elevation (m. AD)	Casing Stickup (m.AGS)	5 APRIL 88 Water Level Measured (m. BTOC)	5 APRIL 88 Water Level Elevation (m.ASL)	15 APRIL 88 Water Level Measured (m. BTOC)	15 APRIL 88 Water Level Elevation (m.ASL)		3 MAY 88 Water Level Measured (m. BTOC)	3 MAY 88 Water Level Elevation (m.ASL)
K-1A	Ontario & Barrack	79.42	.75	4.89	74.53	5.10	74.32		5.07	74.35
K-1B	Ontario & Barrack	79.42	.75	3.24	76.18	4.99	74.43	FT	4.97	74.45
K-2	Gas Holder	80.88	.76	2.80	78.08	2.80	78.08		2.81	78.07
K-3A	Behind Police Station	78.86	.69	4.17	74.69	4.22	74.64		4.18	74.68
K-3B	Behind Police Station	78.86	.69	3.56	75.30	4.23	74.63		4.24	74.62
K-4	Power Station/King St.	80.67	.59	4.45	76.22	4.45	76.22		4.46	76.21
K-5A	E.of PUC Offices	80.60	.71	5.73	74.87	6.00	74.60		5.98	74.62
K-5B	E.of PUC Offices	80.60	.71	3.77	76.83	3.80	76.80		3.90	76.70
K-6A	OHIP Parking Lot	77.94	.56	3.14	74.80	3.22	74.72		3.27	74.67
K-6B	OHIP Parking Lot	77.94	.56	2.80	75.14	2.89	75.05		2.98	74.96
Bay	Anglin Bay W.L.	76.02							1.19	74.83

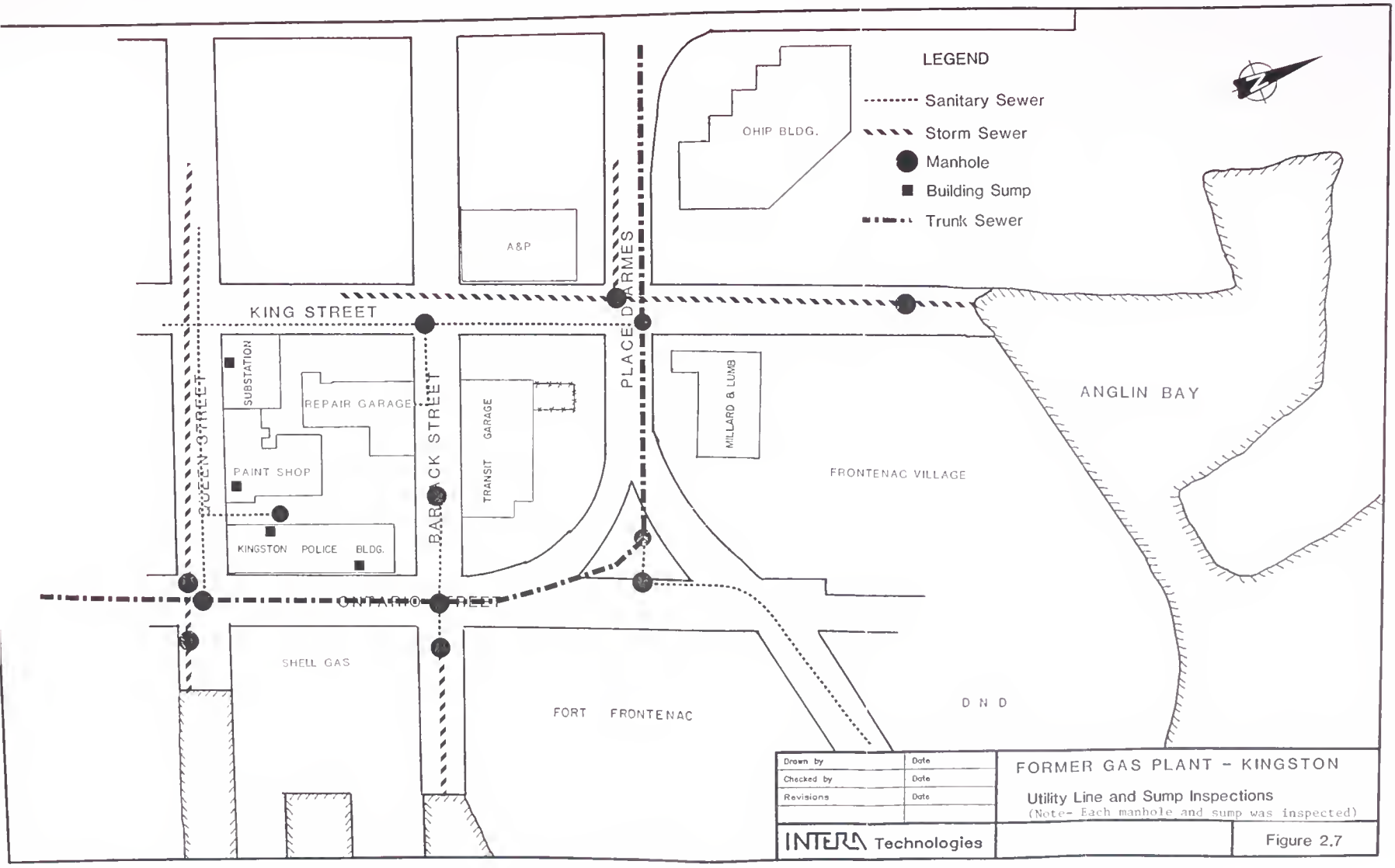
NOTE : 1) Water levels for all wells are measured with respect to the top of the steel casing cap with lid removed.

NOTE : 2) Elevations (m. ASL) are in meters above mean sea level w.r.t. a geodetic datum.

FT = Free tar

on Figure 2.7 were inspected with the assistance of the City of Kingston Works Department for evidence of coal tar contamination or odours. None of the manholes inspected had any indication of coal tar contamination.

An inspection of building sumps was completed to determine if contaminated water was seeping into on-site buildings. Sumps in the police station (two locations), the electrical substation, and the building inspection office were included in this survey. The main sump in the police station had a slight odour of coal tar while the other three sumps were free of odours. One sample was collected from each of the two pipes discharging to the sewer to determine the PAH concentration of the water. The analytical results and the interpretation of the results are described in Section 3.


LEGEND
Sanitary Sewer
Storm Sewer
Manhole
Building Sump
Trunk Sewer
OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
QUEEN STREET
BARRACK STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
KINGSTON POLICE BLDG.
TRANSIT GARAGE
MILLARD & LUMB
ANGLIN BAY
FRONTENAC VILLAGE
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
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FORMER GAS PLANT - KINGSTON
Utility Line and Sump Inspections
(Note- Each manhole and sump was inspected)
Figure 2.7

3. INTERPRETATION OF RESULTS

3.1 HISTORICAL REVIEW

3.1.1 Gas Plant History

The Kingston Gas Plant began operation in about 1848. By 1864, the Kingston Gas Light Company had been formed and by 1881 the plant employed seven people with the total value of production estimated at $14,000 (Can. Census, 1881). In 1892, the gas plant was listed in the Ontario Gazateer (1892 - 1893) as the Kingston Light, Heat and Power Co. with total capital of $100,000. The City of Kingston acquired the plant from private interests on August 1, 1904. At this time, the plant was a retort gas operation producing in one year about 26,652 million cubic feet (m.c.f) of gas (Canadian Gas Association, 1970). (Note: 1 ton of coal produced about 11,000 cubic feet of gas and 70 - 120 lbs. of coal tar.) The gas plant and the production of gas for consumers became the responsibility of the Kingston Public Utilities on January 1, 1914. By 1925, as reported by the Canadian Gas Association (1970), the retort gas process was replaced by a carburetted water gas process. Two sets of Merrifield-Westcott gas producers were in operation in 1930 - 1935 but by 1937 - 1939 only one was in use producing 90,000 m.c.f. while one was idle (capacity of 70,000 m.c.f.). By 1950 the gas plant was abandoned and replaced by a propane air mix plant.

3.1.2 Gas Plant Operation

The Kingston Gas plant likely used three different gas manufacturing processes; retort gas, blue gas and carburetted water gas during its history.

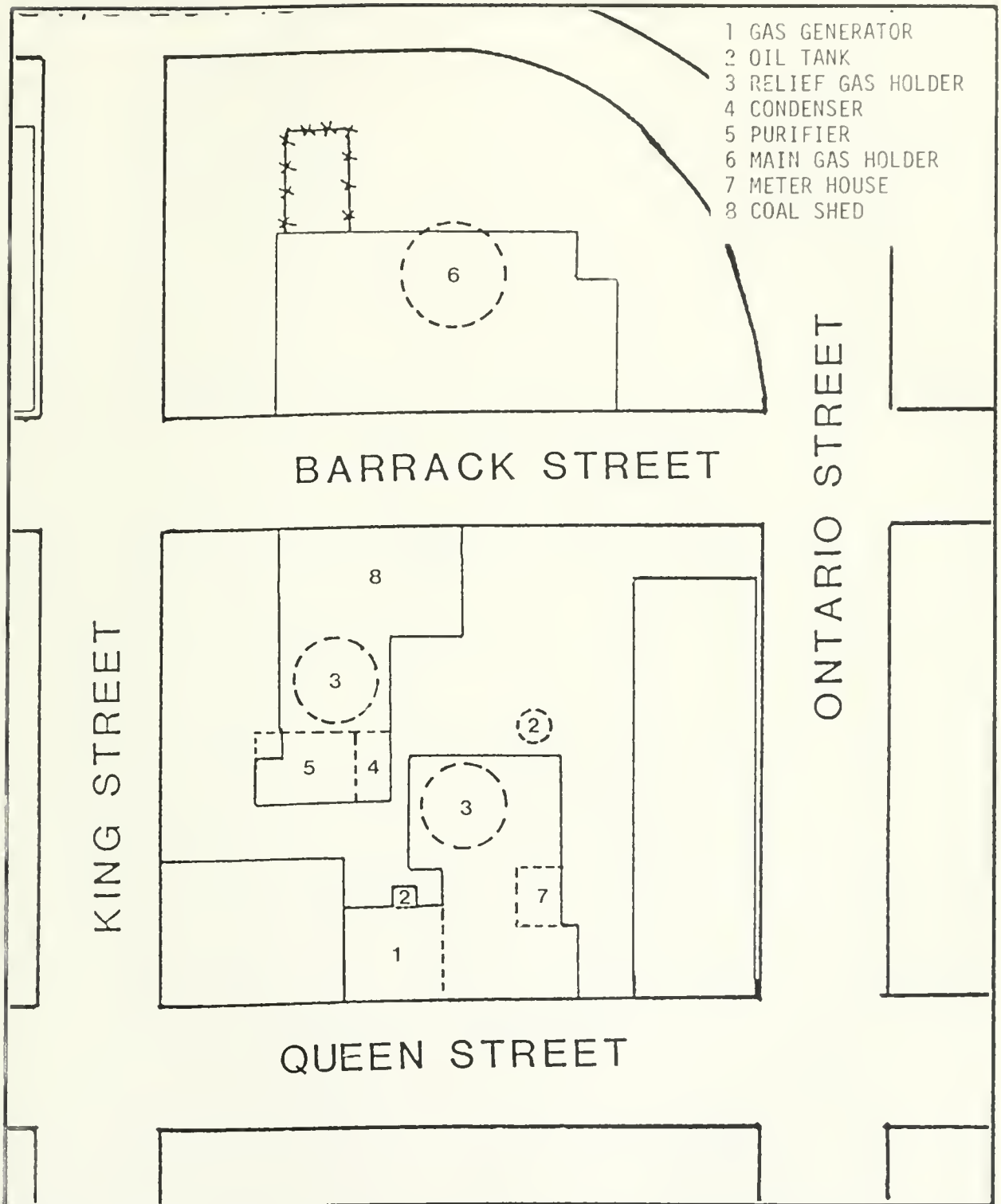
The retort gas process was a relatively simple gas generating process which, in Kingston, was probably used in its earliest stages

beginning in 1848. The retort gas process consisted of feeding coal into a vertical or horizontal retort (initially probably a horizontal retort but later replaced by a vertical retort) and carbonizing (burning in a closed vessel) the coal to produce coke and retort gas. In Kingston, it appears steam was added to the hot coke and retort gas to produce blue gas (also called water gas) and to substantially increase the gas yield. This process was likely completed in cycles, first combusting the coal/coke using air blasts then passing steam through the hot fuel bed.

At Kingston, the blue gas was also enriched by cracking oil in the presence of the gas and steam. This process was called carburetted water gas and produced a gas that is high in heating value. The oil was typically a Bunker "C" type oil. The process consisted of adding oil, in a spray, to the blue gas in a carburetor. The mixture was then heated in a superheater which cracked the oil to more simple gases. As in the blue gas process, the carburetted water gas was generated in cycles.

Once the gas had been generated it was necessary to cool and clean the gas before it could be sold to consumers. Prior to cleaning the gas was stored in a relief gas holder. The clean-up process usually consisted of condensing the gas and scrubbing the gas with water to remove the tars, oils and water from the gas. The tars, oils and water were usually separated by gravity and stored in on-site underground tanks known as tar wells. The gas was then passed through oxide boxes in a purifying house to remove sulphur. When the gas was clean it was stored in the main gas holder prior to being distributed to consumers. The gas was distributed through a metering house.

On the Kingston site, the locations of most of the gas plant structures mentioned above can be identified. Using historical fire insurance maps, the buildings of the gas plant can be compared to the present on-site buildings for the periods 1908 (Figure 1.3 and 3.1) and 1924 (Figures 1.4 and 3.2).

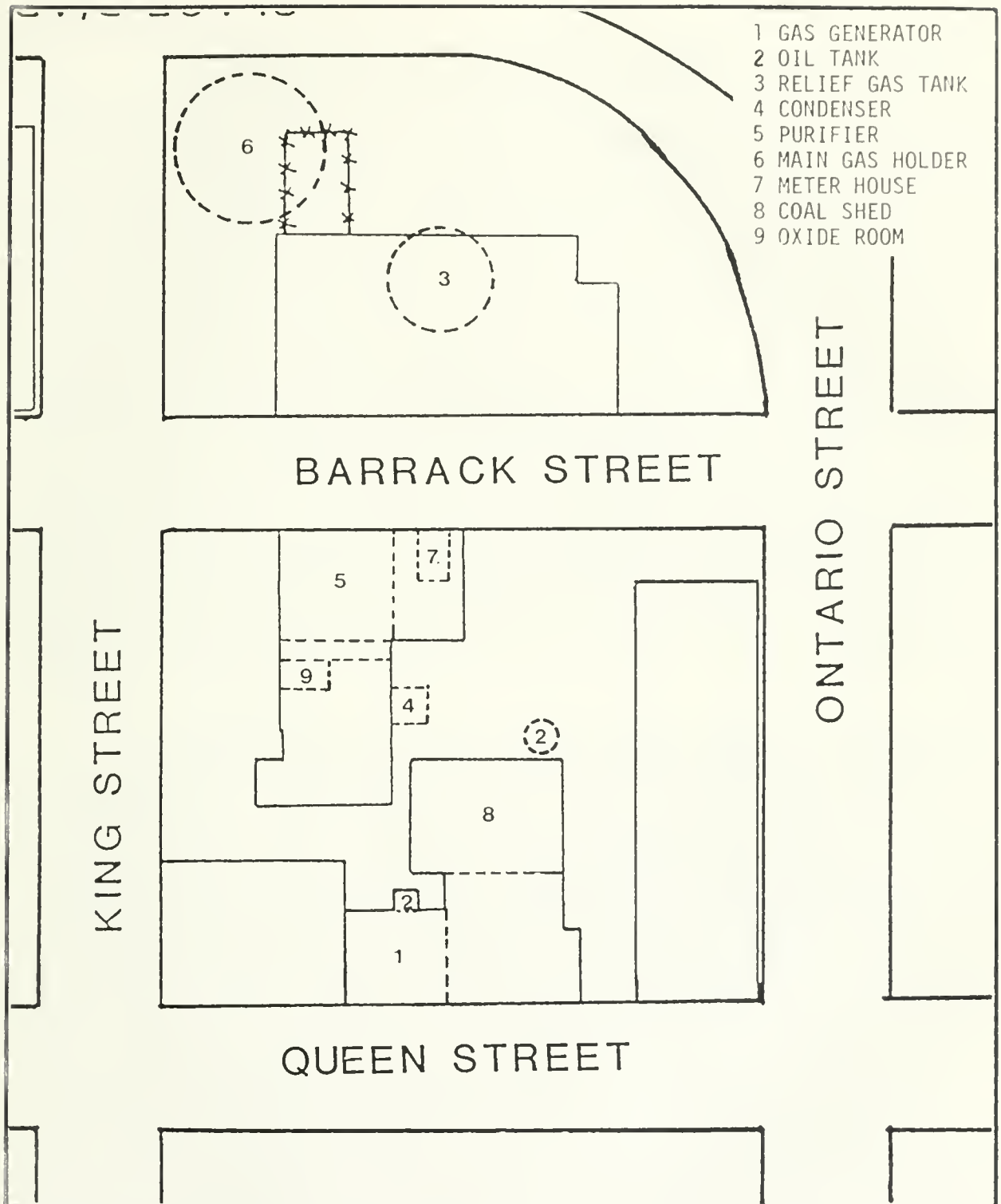


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COMPARISON OF 1908 GAS PLANT BUILDINGS TO THE PRESENT SITE BUILDINGS

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FIGURE 3.1



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COMPARISON OF 1924 GAS PLANT BUILDINGS TO THE PRESENT SITE BUILDINGS

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FIGURE 3.2

In 1908, the gas generator or retort house (1) was located on Queen Street east of the electrical substation. The original building is still standing and presently houses commercial businesses. The gas may have been supplemented by oil in a carburetted water gas process using the oil tanks (2) but in 1908 this process was not in common use in Canada. If water gas was not in use then the purpose of on-site oil tanks is unknown unless they were used for oil-tar storage or as fuel in the retort house. The gas after it was produced would have been stored in the relief gas holder(s) (3). In 1908, two relief gas holders, one in what is now the PUC paint shop and one in the area of the present PUC repair garage were present on-site. The outline of the gas holder in the paint shop is still evident in the floor of the original buildings. It is unlikely that both of the relief gas holders were used at the same time. The usual practice was to abandon older tanks as newer, larger tanks were built and therefore one of the tanks may have been an earlier relief holder while the other was a main gas holder.

The gas cleaning area was located in the area of the present repair garage. The condenser (4) was located in the southeast corner of the building. The tar wells may have been located underground in this area but the exact location is not identified on any maps. The purifying house (5) adjacent to the condenser would have contained the oxide boxes for removal from the sulphur and possibly storage areas for iron oxide. Parts of the condenser and purifying house may remain on-site in its present use as a PUC office and locker room. The clean gas, ready for distribution, was stored in the main gas holder (6) located in the Barrack/Place D'Armes block. The surface structure of the gas holder has been removed and the area is occupied by a PUC bus garage. The meter house (7) was used to pump the gas to consumers and to regulate the gas flow. The meter house is still in use as a city parking meter repair shop.

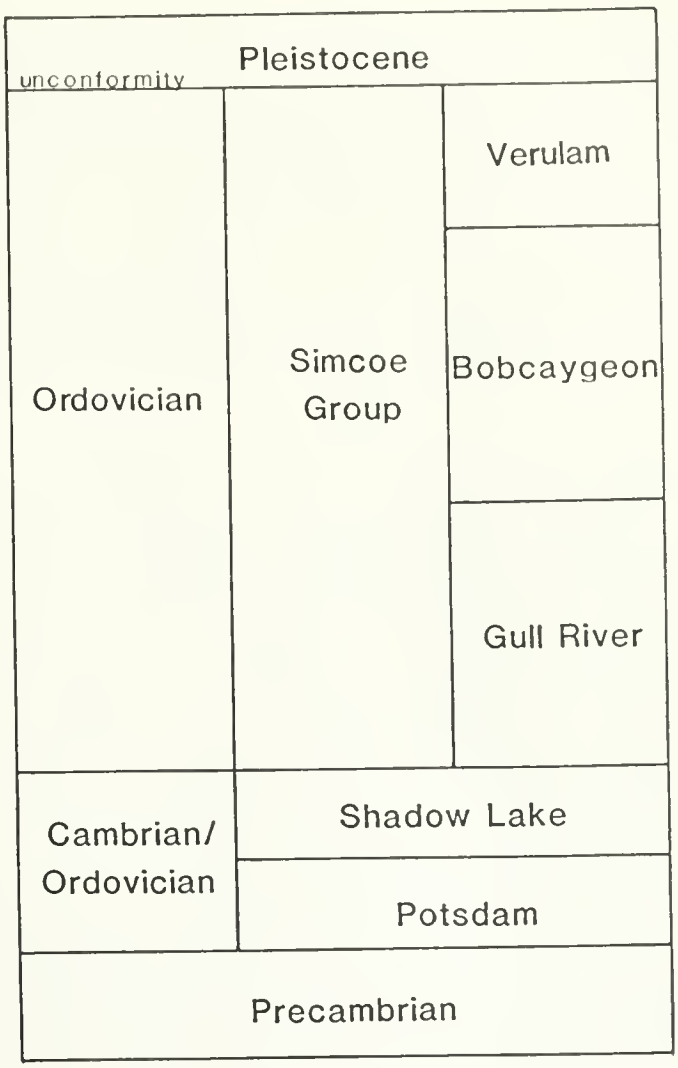
By 1924, the gas plant layout had changed. The gas producers (1), by this time were two carburetted water gas producers located in the same building. The oil tanks (2) were likely used to add oil to the gas mixture during the gas generating process. The produced gas was stored in a relief gas holder (3, the former main gas holder) on the Barrack/Place D'Armes block. The condenser house (4) was located in a small building near to the original 1908 location (Note that the condenser house is not identified on the 1924 map but was located on a PUC property plan). In all probability, the same tar wells would have been used in the condenser house. The purifying house (5) in 1924 was located off of Barrack St. in the area of the coal shed in 1908 and the present location of the bus wash. The cleaned gas was stored in a main gas holding tank (6) on the corner of King and Place D'Armes. The outline of the main gas holding tank is still visible in what is now a parking lot. The gas was distributed through the meter house (7) located adjacent to the purifying house. An oxide storage room (9) was located off of the purifying house.

3.2 SITE GEOLOGY

3.2.1 Regional Geology

The regional geology of the Kingston area consists of Paleozoic strata overlying the Precambrian rocks of the Canadian Shield and underlying surficial deposits of Pleistocene age. The regional geologic cross section is given in Figure 3.3.

The Precambrian rocks consist primarily of granite and crystalline limestone of the Grenville Province. The Frontenac Axis, a northwest - southeast trending uplift area of the Canadian Shield, is located to the east of Kingston. The Precambrian rocks are exposed in the bottom of the Cararaqui River to the north but are typically at



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Stratigraphic Column - Kingston Area

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Figure 3.3

depths of 30 to 60 metres in the Kingston area. The surface of the Precambrian rocks tend to influence the surface of the Paleozoic rocks with the Paleozoic rocks draped over the Precambrian surface. The Precambrian geology is described in detail by Wynne-Edwards (1967).

The Paleozoic stratigraphy comprises rocks of Cambrian (500 to 570 million years before present) and Ordovician (440 to 500 million years before present) ages. The Potsdam sandstone lies unconformably on the Precambrian basement and is generally accepted to be of Cambrian or late Ordovician age. The Potsdam Formation is a red and pink to white, grey and yellow sandstone and siltstone. The Potsdam is overlain by the Shadow Lake Formation, deeply weathered red, black and green shales, sandstones and arkoses (Liberty, 1971).

The Simcoe Group comprises carbonate strata lying conformably above the Shadow Lake Formation. This group can be divided into four formations: Gull River, Bobcaygeon, Verulam and Lindsay in ascending order. The thickness of the Simcoe Group increases to the west. The Gull River Formation, which is typically 60 to 70 m in thickness, consists of fine crystalline or lithographic limestone with thin shale interbeds or shale parting in the upper members. The Bobcaygeon Formation, which is 12 to 22 m thick, is a thin bedded, grey, calcarenitic and sublithographic limestone whereas the Verulam Formation which is 60 to 90 m thick consists of interbedded fine and medium crystalline limestone and weathered calcareous claystone with shale partings. The regional dip of the Paleozoic strata in the area is about 1.9 to 2.8 m per kilometre to the south and southwest. The strike of the regional stratigraphic units is from east to southeast. Locally, however, where the Precambrian is tilted, the strike may be northeasterly resulting in a minor southeasterly dip (Peterson, 1969).

The Pleistocene age deposits consist of a thin veneer of glacial drift covering most of the area. Thin irregular deposits of glacial till and a few eskers and drumlins overlie Paleozoic sediments in the Kingston area. Glacial lacustrine deposits consisting of mostly

clay and silt and minor sand and gravel or beach deposits are found covering most of the region.

3.2.2 Local Geology

For the Kingston Gas Plant site and surrounding property, the shallow geology is relatively simple and is consistent with the regional geology. Based on the results of boreholes drilled as part of this study and boreholes from city sewer construction (see Figure 2.5 and Appendix C), the overburden is relatively thin, on the order of 1.5 to 7.6 metres in thickness and overlies limestone bedrock of the Gull River Formation. The geology of the site is illustrated in an east-west cross-section in Figure 3.4 and in a north-south cross-section in Figure 3.5. The lines of cross-section are illustrated in Figure 2.5.

The overburden material consists of fill, lacustrine clay and glacial till from the surface down. The fill material is variable in nature consisting of clay, sand, gravel, cinders, ash, coal, asphalt, concrete and boulders depending on the location. In all areas of shallow bedrock (i.e., within 2 m of surface) especially on the former gas plant property the fill material extends to the bedrock surface. In these locations, the fill is predominantly a disturbed, dense brown, weathered clay. There was evidence of coal tar waste materials in the fill material in borehole K4 adjacent to the electrical substation and in borehole K2 in the area of the main gas holder. In borehole K4 an oily hydrocarbon product with a coal tar odour was found from about 1.0 metre below surface to the top of rock at about 2.7 metres below surface. When drilling borehole K2 which was located on top of the former gas holding tank approximately 7.7 m of fill material above bedrock was intersected. It is possible that the gas holding tank was excavated into rock for construction and then backfilled when it was abandoned. The fill material in the main gas holding tank consists of dense clay at surface to about 2.2 metres below surface and then coarse

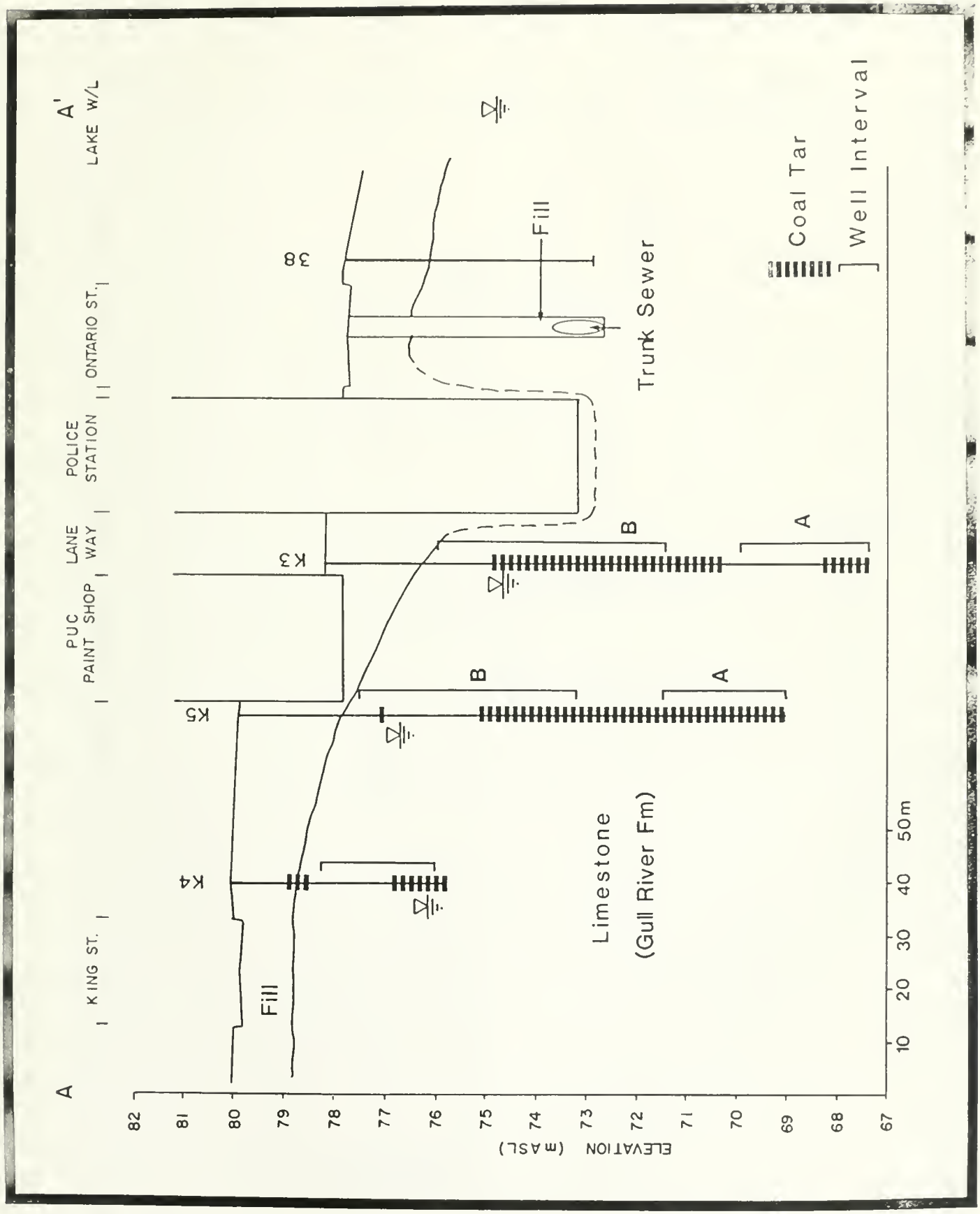


FIGURE 3.4 GEOLOGIC CROSS SECTION IN AN EAST-WEST DIRECTION

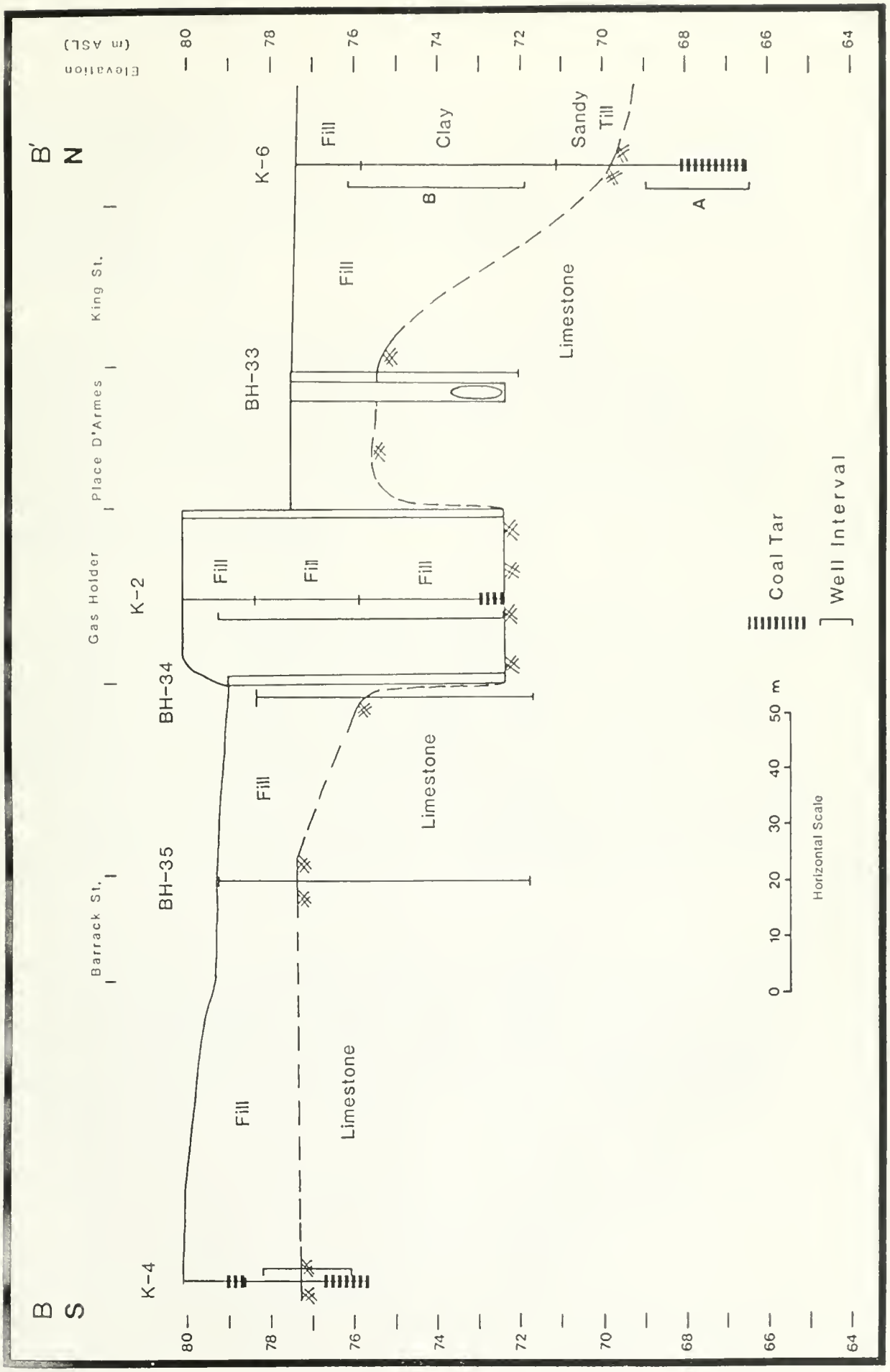


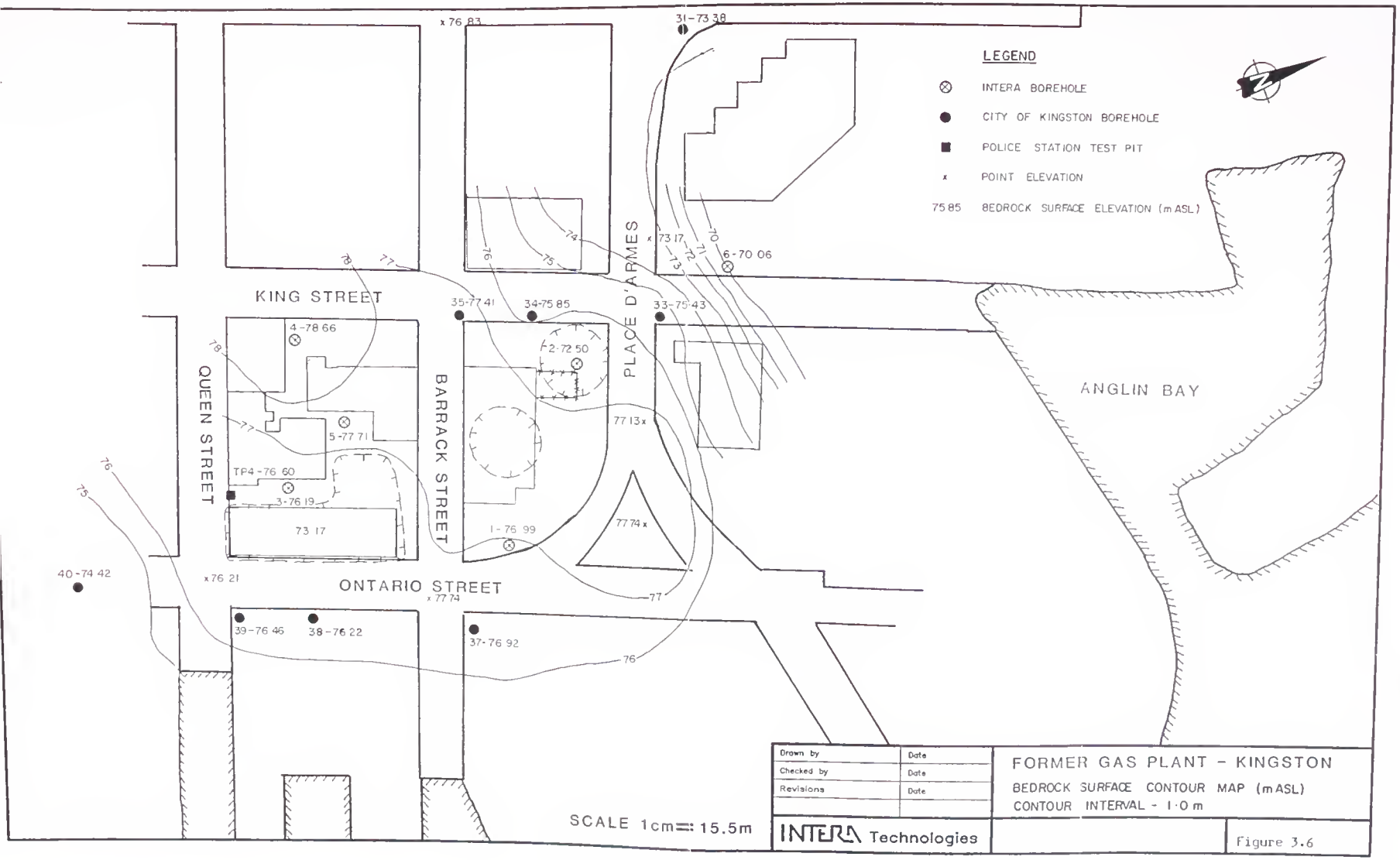
FIGURE 3.5 GEOLOGIC CROSS SECTION IN A NORTH-SOUTH DIRECTION

gravel and boulders to the top of rock. The gravel and boulder material is very porous as evidenced by the lack of cutting return during auguring. It is estimated that the porosity is about 50 to 75% in this material. Free coal tar was also found in this borehole in the last 0.6 m above bedrock.

The only borehole that intersected substantial thicknesses of overburden was borehole K6 located in the OHIP parking lot. This borehole intersected 7.5 m of fill and overburden above bedrock. The upper 2.0 metres consisted of fill underlain by dark grey mottled, hard clay. The clay material is likely a glacial lacustrine deposit. The clay extends to 6.4 metres below surface. A sandy till with gravel is found immediately above bedrock.

The bedrock in the area of the former gas plant is the Gull River Formation and the Bobcaygeon and Verulam Formations were not found at this site. The Gull River is typically a grey finely crystalline limestone with thin shale seams and stylolites. Occasionally, the shale seams are weathered to a muddy clay. The limestone is relatively massive with only occasional horizontal bedding planes. The rock quality of cores is generally good for shallow bedrock and there is little evidence of weathering at the bedrock surface.

The bedrock surface is illustrated in Figure 3.6. Generally the bedrock surface is relatively flat to gently undulating. The bedrock surface increases in depth below surface to the east and especially to the north in the area of borehole K6. Bedrock is exposed at surface to the northwest of the site in the area of Bay Street and Montreal Road.


LEGEND
INTERA BOREHOLE
CITY OF KINGSTON BOREHOLE
POLICE STATION TEST PIT
x POINT ELEVATION
7585 BEDROCK SURFACE ELEVATION (m ASL)
KING STREET
QUEEN STREET
BARRACK STREET
PLACE D'ARMES
ONTARIO STREET
ANGLIN BAY
x 76 83
31-73 38
x 73 17
6-70 06
35-77 41
34-75 85
33-75 43
4-78 66
2-72 50
5-77 71
TP4-76 60
3-76 19
73 17
1-76 99
7713x
7774x
x 77 74
40-74 42
x 76 21
39-76 46
38-76 22
37-76 92
SCALE 1cm = 15.5m
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Date
INTERA Technologies
FORMER GAS PLANT - KINGSTON
BEDROCK SURFACE CONTOUR MAP (m ASL)
CONTOUR INTERVAL - 1·0 m
Figure 3.6

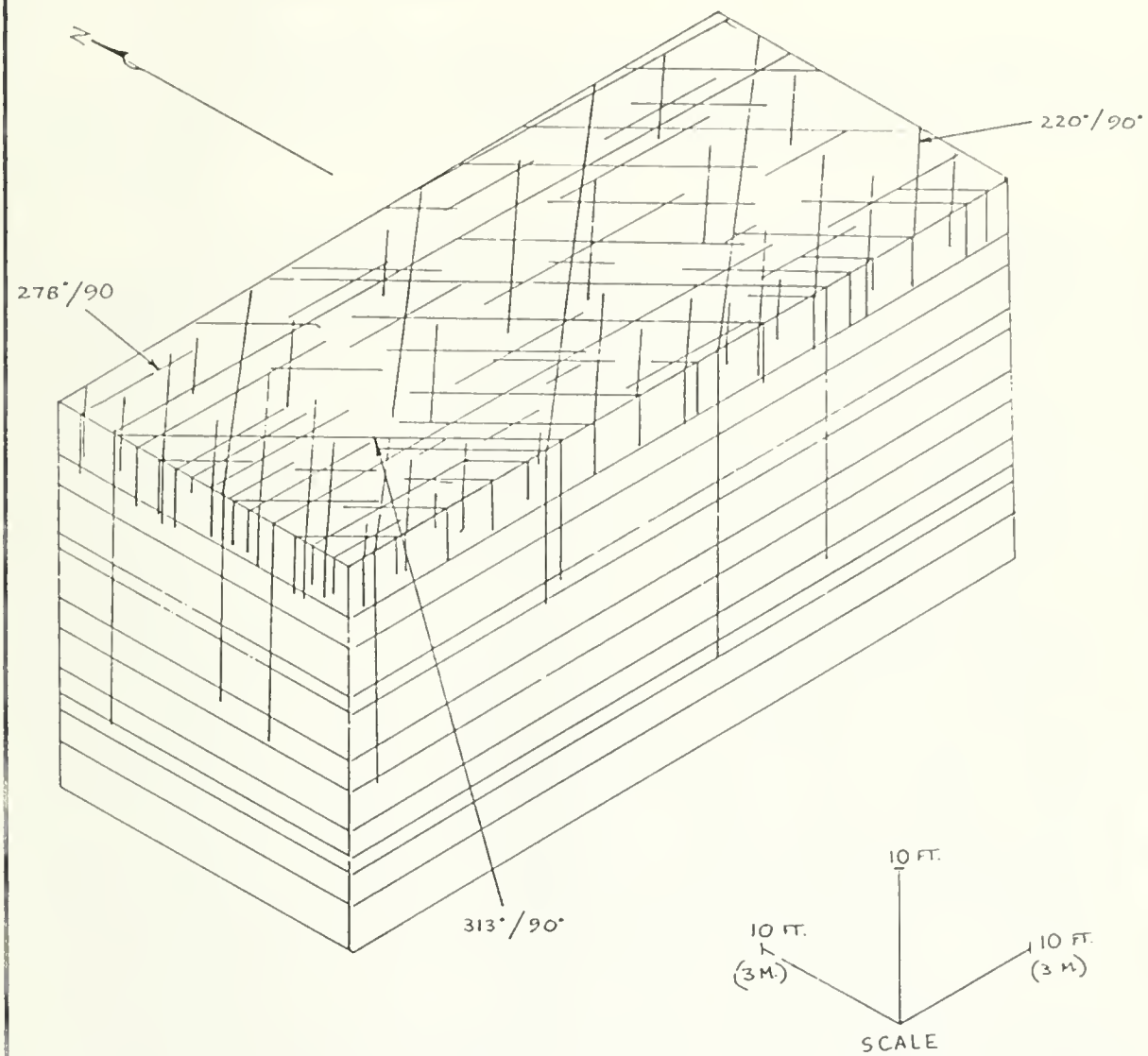
Structurally, the bedrock is relatively sound and is broken only by bedding planes and joints. The bedding planes are commonly at shale partings and typically spaced on average every 0.6 m based on observations of the core. The bedding planes are usually open but may be infilled with calcite. The orientation of the bedding planes is assumed the same as the regional trend: striking to the east-southeast and dipping to the south - southwest at 1 to 2 metres per kilometre however strike and dip measurements were not obtained from the boreholes.

Jointing in the Paleozoic bedrock in the Kingston area has been studied by Bawden (1970), Clark (1959) and Peterson (1969) and they have found four major joint sets. The four major joint sets are illustrated in Figure 3.7 and listed as follows:

- Strike 220° Dip 90°
- Strike 313° Dip 90°
- Strike 225° Dip 90°
- Strike 278° Dip 90°

These joint sets generally have spacings of 1 to 3 m.

During the drilling program considerable coal tar contamination was found in the bedrock. As soon as the "tar-bearing" zones were intersected there was a noticeable odour at the top of the augers and in the mud tank and the mud return water had an obvious oily sheen to it. Upon retrieval of the core runs, free coal tar was often found coating the bedding planes or as blobs stuck to the surface of the fractures indicating that coal tar may be migrating along the bedding plane. Free tar did not appear to have penetrated the intact rock although intact cores also had distinct odours of coal tars.



(from Bawden, 1970)

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MAJOR JOINT SETS IN THE PALEOZOIC BEDROCK IN THE KINGSTON AREA

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FIGURE 3.7

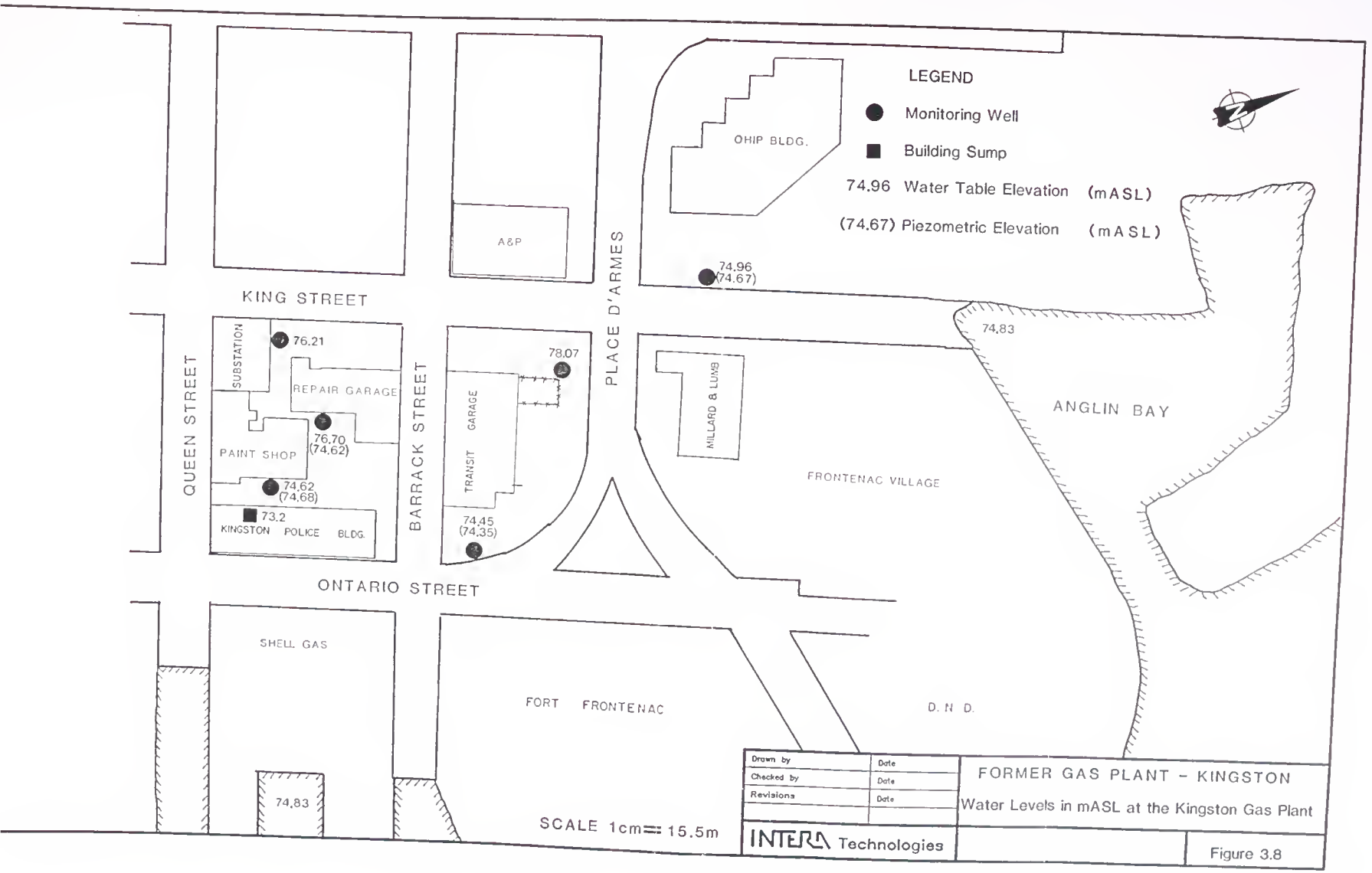
3.3 SITE HYDROGEOLOGY

3.3.1 Groundwater System

The groundwater system in the area of the former Kingston gas plant, like other urban environments is complicated by man-made influences.

The shallow groundwater on the gas plant site is contained in the bedrock with the water table at depths of about 2 to 5 metres below surface. Groundwater flow in the bedrock is primarily along the bedding planes and joints within the rock and to a lesser extent in the pore spaces of the intact rock. On a regional scale, the groundwater flow direction would be directed towards the Cataraqui River and Lake Ontario. At the site, groundwater flow is influenced more by man-made structures than the regional flow. The water table levels and piezometric elevations on May 3, 1988 for all of the monitoring wells are given in Table 2.4 and Figure 3.8. Although the monitoring wells are limited in areal extent, it is possible to make some generalizations regarding the groundwater flow on-site. The low point on-site is the building sump in the basement of the police station which is at an elevation of about 73.2 m ASL which is lower than the water level in Lake Ontario. This sump is connected to the foundation drains and collects groundwater surrounding the building. The total flow to the sumps from the drainage pipes was estimated to be in the range of 90 to 180 L/min on May 4, 1988. Because of the high flow to the sump the groundwater flow in the area of the building is directed to the foundation drains.

In addition to the building sump in the police station, storm and sanitary sewers may also have an influence on the groundwater flow. Of primary concern is the sanitary trunk sewer that runs along the


LEGEND
Monitoring Well
Building Sump
74.96 Water Table Elevation (mASL)
(74.67) Piezometric Elevation (mASL)
OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
74.96
(74.67)
74.83
ANGLIN BAY
MILLARD & LUMB
FRONTENAC VILLAGE
QUEEN STREET
SUBSTATION
76.21
REPAIR GARAGE
76.70
(74.62)
PAINT SHOP
74.62
(74.68)
73.2
KINGSTON POLICE BLDG.
BARRACK STREET
TRANSIT GARAGE
78.07
74.45
(74.35)
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D. N. D.
74.83
SCALE 1cm = 15.5m
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FORMER GAS PLANT - KINGSTON
Water Levels in mASL at the Kingston Gas Plant
Figure 3.8

centre of Ontario Street and up Place D'Armes. This sewer (invert elevation 72.56 m ASL) would act as a permeable conduit in the bedrock and a preferential flow pathway for groundwater.

In the area of monitoring well K2, it is likely that the water level (78.07 m ASL) is perched on top of the former gas holding tank because the water level is significantly above the water levels for the rest of the site. The perched water table is caused by the walls of the tank and essentially the tank acts as a "bathtub". Seepage from the "bathtub" likely occurs through cracks in the walls or base or from holes in the walls caused by utility line construction.

In the area of monitoring well K6, the water table is located in the overburden at an elevation of 74.96 m ASL and the groundwater likely flows towards Anglin Bay (water level elevation of 74.83 m ASL).

Horizontal hydraulic gradients for the water table can not be estimated with accuracy because the monitoring well network is not a really extensive and the water table is influenced by man-made factors. The gradient is, however, the greatest in the area of the police station because of the influence of the building sump.

The vertical hydraulic gradients are similarly affected by on-site man-made structures. Of the four boreholes in which there are two monitoring wells, three of the locations (K1, K5 and K6) have downward gradients which indicates the water table is recharging the deeper bedrock while one location (K3) indicates that the groundwater flow is directed upward probably towards the sump in the police station.

The hydraulic conductivities determined from slug testing of the monitoring wells were given in Table 2.3. The hydraulic conductivities in the bedrock range from 2.6×10^{-9} to 1.5×10^{-6} m/s with an average of 2.5×10^{-7} m/s and a single overburden (clay/till) result yields an average value of 1.6×10^{-7} m/s. For the bedrock the

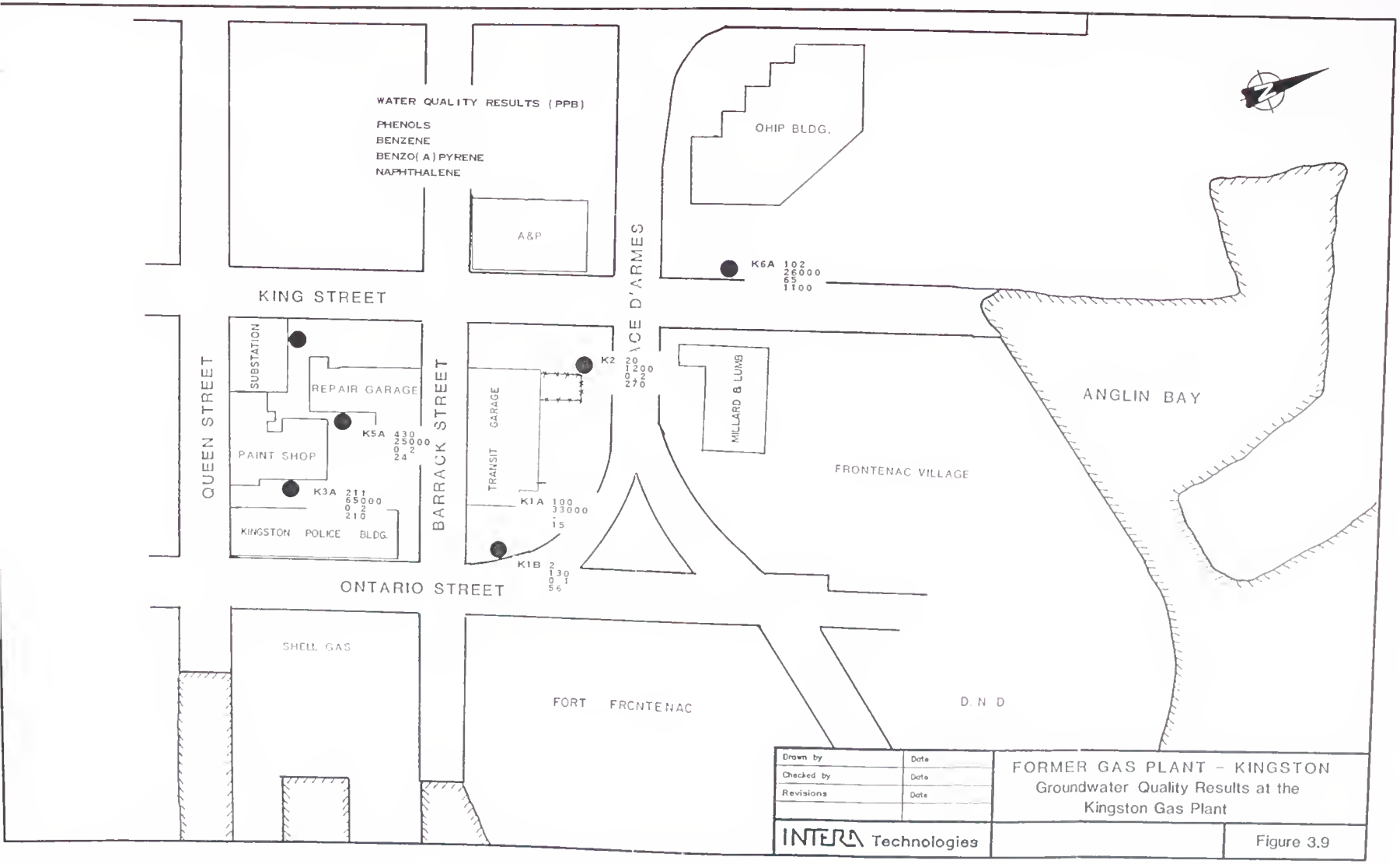
range of values are typical for a limestone formation (Freeze and Cherry, 1979). The wide range of values represents the fractured nature of the bedrock. Test intervals containing several open bedding planes or joints will have higher hydraulic conductivities than those intervals containing intact rock. Because the bedrock contains shale interbeds, bedding planes and joints, the hydraulic conductivity is dependent on position within the formation (i.e., heterogeneity) and the direction of measurement (i.e., anisotropy). Higher hydraulic conductivities are likely to be found parallel to the major joint orientation and along bedding planes.

During the slug testing in K2, the water level recovery was too fast to measure. A fast response in a slug test usually indicates a hydraulic conductivity greater than 1×10^{-4} m/s. This high value is consistent with the "bathtub" affect in that if the area was not contained the high permeability material would not support a perched water table.

3.3.2 Groundwater Quality

The complete water quality analyses for the six monitoring wells that were sampled are given in Appendix E. This section provides an interpretation and discussion of the significance of the results. The interpretation of the results is based on a one-time sampling event.

Coal tar waste in the form of free coal tar was encountered in each of the boreholes drilled as part of the site investigations and therefore the water quality reflects this contamination. Because contamination was found in each of the sampled wells, a background water quality can not be determined. Wells such as K1B, K2 and K6A contain free coal tar. A comparison of the water quality between wells is given in Figure 3.9 using the organic contaminants phenol, benzene, benzo(a)pyrene, and napthalene. These parameters are


WATER QUALITY RESULTS (PPB)
PHENOLS
BENZENE
BENZO(A)PYRENE
NAPHTHALENE
A&P
OHIP BLDG.
KING STREET
K6A 102 26000 65 1100
QUEEN STREET
SUBSTATION
REPAIR GARAGE
K5A 430 25000 0.2 24
PAINT SHOP
K3A 211 65000 0.2 210
KINGSTON POLICE BLDG.
BARRACK STREET
TRANSIT GARAGE
K2 20 1200 0.2 270
K1A 100 33000 15
K1B 2 130 0.1 56
ONTARIO STREET
PLACE D'ARMES
MILLARD & LUMB
ANGLIN BAY
FRONTENAC VILLAGE
SHELL GAS
FORT FRONTENAC
D.N.D
N
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INTERA Technologies
FORMER GAS PLANT - KINGSTON
Groundwater Quality Results at the Kingston Gas Plant
Figure 3.9

reliable indicators of coal tar because they are all components of tar and represent soluble (i.e., phenol and benzene) and less soluble (i.e., naphthalene and benzo(a)pyrene) compounds.

The phenol concentrations range from 2 to 430 ppb and are highest in the area of boreholes K3 and K5. Phenol has a high solubility (over 10,000 ppm), low vapour pressure and low adsorption coefficient and therefore it tends to migrate with the groundwater. The fact that the concentrations are relatively high (background concentrations are probably 1 - 2 ppb) indicates that there is a possible source on-site which is generating leachate containing phenols. Phenol concentrations in the grounwater generally exceed MOE desirable concentrations for drinking water (2 ppb) and water quality objectives (1 ppb).

The concentrations of benzene as well as other aromatic hydrocarbons (Table 3.1) (toluene, xylene and ethylbenzene) are very high in the groundwater. Benzene concentrations range from 130 to 65000 ppb and generally exceed Canadian drinking water guidelines of 5 ppb and MOE water quality guideines of 250 ppb. The concentrations are highest in the bedrock (i.e., K1A-33000 ppb, K3A-65000 ppb) while monitoring wells closer to surface (i.e., K1B-130 and K2-1200 ppb) are lower. The differences are likely due to volatilization. In the bedrock, the aromatic hydrocarbons and vapours that may be generated are contained by the rock while in shallower water table wells the groundwater is in contact with the air and volatilization, resulting in a decrease in concentration, can readily occur. A similar affect is seen in the other aromatic hydrocarbons. An example of this is in well K2, which contains free coal tar and is a water table well but has relatively low concentrations of aromatic hydrocarbons as compared to deeper bedrock wells such as K1A or K3A. The bedrock restricts the vertical migration of the vapours from the aromatic hydrocarbons and this is a likely reason why the soil gas sampling did not detect more widespread contamination.

TABLE 3.1 CONCENTRATION OF VOLATILE PRIORITY POLLUTANTS IN GROUNDWATER (ppb)

COMPOUND	K6A-1	MDL	K1A-1	K3A-1	K5A-1	MDL	K1B-1	K2-1
BENZENE	26000	200	33000	65000	25000	100	130	1200
BROMODICHLOROMETHANE	-	200	-	-	-	100	-	-
BROMOFORM	-	400	-	-	-	200	-	-
BROMOMETHANE	-	3200	-	-	-	1600	-	-
CARBON TETRACHLORIDE	-	400	-	-	-	200	-	-
CHLOROBENZENE	-	200	-	-	-	100	-	-
CHLOROETHANE	-	2000	-	-	-	1000	-	-
2-CHLOROETHYL VINYL ETHER	-	2000	-	-	-	1000	-	-
CHLOROFORM	-	200	-	-	450	100	-	-
CHLOROMETHANE	-	10000	-	-	-	5000	-	-
DIBROMOCHLOROMETHANE	-	200	-	-	-	100	-	-
1,2-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,3-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,4-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,1-DICHLOROETHYLENE	-	200	-	-	-	100	-	-
1,1-DICHLOROETHANE	-	200	-	-	-	100	-	-
1,2-DICHLOROETHANE	-	400	-	-	-	200	-	-
TRANS-1,2-DICHLOROETHYLENE	-	200	-	-	-	100	-	-
DICHLOROMETHANE	-	3000	-	-	-	1500	-	-
1,2-DICHLOROPROPANE	-	200	-	-	-	100	-	-
CIS-1,3-DICHLOROPROPENE	-	200	-	-	-	100	-	-
TRANS-1,3-DICHLOROPROPENE	-	200	-	-	-	100	-	-
ETHYLBENZENE	10000	200	1000	2900	280	100	160	290
A-METHYLSTYRENE	-	200	-	-	-	100	-	-
METHYLSTYRENE ISOMERS	1100	200	800	580	420	100	89	176
MESITYLENE	-	200	-	-	-	100	-	-
1,1,2,2-TETRACHLOROETHANE	-	400	-	-	-	200	-	-
TETRACHLOROETHYLENE	-	200	-	-	-	100	-	-
TOLUENE	22000	400	19000	24000	9800	200	170	450
1,1,1-TRICHLOROETHANE	-	400	-	-	-	200	-	-
1,1,2-TRICHLOROETHANE	-	200	-	-	-	100	-	-
TRICHLOROETHYLENE	-	200	-	-	-	100	-	-
TRICHLOROFLUOROMETHANE	-	400	-	-	-	200	-	-
M+P-XYLENE	5700	200	3200	4000	1100	100	190	220
O-XYLENE	2100	200	1100	1700	550	100	120	100
VINYL CHLORIDE	-	2400	-	-	-	1200	-	-
OTHER AROMATIC COMPOUNDS	2600	200	600	730	190	100	220	320
STYRENE	5500	400	6900	6000	5000	200	110	880

MDL = METHOD DETECTION LIMITS

OTHER AROMATIC COMPOUNDS = Total concentration of trimethylbenzenes using the response factor of mesitylene.

Naphthalene and benzo(a)pyrene are both polycyclic aromatic hydrocarbons but have different physical and chemical properties. Naphthalene with a molecular weight of 128 is soluble in water to 32 ppm, has a high volatilization and relatively low adsorption. Benzo(a)pyrene has a molecular weight of 252, a solubility of 3.8 ppb, a low volatilization and high adsorption. In the groundwater naphthalene was found in all wells at concentrations ranging from 15 to 1100 ppb due in part to its high solubility. Similarly other PAH that are relatively soluble such as acenaphthylene, fluorene, phenanthrene, and anthracene are also found in high concentrations. The PAH concentrations in the groundwater are given in Table 3.2. Benzo(a)pyrene on the other hand is relatively insoluble and is found in high concentrations only in wells that contain free product (i.e., K6A-65 ppb). The drinking water and water quality guideline for benzo(a)pyrene is 0.01 ppb. Similarly other less soluble PAH are not found in the groundwater at significant concentrations.

In Tables 3.1 and 3.2, the method detection limits are relatively high because of the high concentrations in the samples. To quantify the high concentrations it was necessary to dilute the samples and this raises the detection limit. Low and trace concentrations of some compounds may go undetected under these circumstances.

In general, the inorganic parameters for the six sampled wells show little evidence of contamination however without a background well for comparison it is difficult to assess the potential extent of contamination. Most of the inorganic parameters are below drinking water standards.

The contaminant concentrations in the groundwater are attributed to the coal tar found in each borehole. It is possible that other sources such as solvents from the paint garage or gasoline from a spill at a nearby gas station may be contributing to the contamination in the groundwater. Based on the existing information and the presence of visible tar in the boreholes, other sources of contamination can not be confirmed.

TABLE 3.2 CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN GROUNDWATER (ppb)

COMPOUND	K1a-1	K1b-1	K5a-1	K6a-1	MDL	K3a-1	Lab Blank	MDL	K2-1	MDL
ACENAPHTHENE	12	42	19	100	0.8	16	-	0.05	51	0.05
ACENAPHTHYLENE	33	120	40	2500	0.8	260	-	0.05	110	0.05
ANTHRACENE	11	13	13	290	0.8	19	-	0.05	18	0.05
BENZ(A)ANTHRACENE	0.2	0.3	0.5	110	0.8	0.6	-	0.05	0.7	0.05
BENZO(B) + BENZO(K)FLUORANTHENE	-	0.1	0.1	66	0.8	0.2	-	0.05	0.2	0.05
BENZO(A)PYRENE	-	0.1	0.2	65	0.8	0.2	-	0.05	0.2	0.05
BENZO(GHI)PERYLENE	-	-	-	27	1.5	-	-	0.1	TR	0.1
CHRYSENE	0.2	0.3	0.3	75	0.8	0.5	-	0.05	0.4	0.05
DIBENZ(A,H)ANTHRACENE	-	-	-	11	1.5	-	-	0.1	-	0.1
FLUORANTHENE	2.1	3.7	2.3	160	0.8	4.5	-	0.05	4	0.05
FLUORENE	42	52	42	370	0.8	48	-	0.05	40	0.05
INDENO(1,2,3-CD)PYRENE	-	-	-	26	1.5	-	-	0.1	TR	0.1
NAPHTHALENE	15	56	24	1100	0.8	210	-	0.05	270	0.05
PHENANTHRENE	53	55	55	1000	0.8	78	-	0.05	69	0.05
PYRENE	3.1	5.5	-	280	0.8	5.8	-	0.05	6.3	0.05

MDL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS
(%)

COMPOUND	K1a-1	K1b-1	K5a-1	K6a-1	K3a-1	Lab Blank	K2-1
D8-NAPHTHALENE	*	*	*	*	*	57.8	*
D10-ANTHRACENE	100	100	100	100	100	90.7	100
D10-FLUORANTHENE	76.5	67.8	80.9	71.6	68.7	79.2	76.7
D12-PERYLENE	63.7	57.9	74.5	**	62.4	81.6	52.9

* = Recovery not determined due to high concentration of native naphthalene.

3.3.3 Sediment and Surface Water Quality

Sediment and surface water samples were collected from Anglin Bay and Lake Ontario to assess the potential impact of coal tar waste or contaminated groundwater discharging to these surface waters. The sampling locations are shown in Figure 2.6 and consisted of sediment samples from Anglin Bay at the end of King Street and from Lake Ontario at the end of Queen Street and water samples from Anglin Bay, Lake Ontario and a background sample from the LaSalle Causeway Bridge. The PAH analytical results for the sediment samples are given in Table 3.3 and the surface water in Table 3.4.

The Anglin Bay sediment sample (K-sed-1) has higher concentrations than the Lake Ontario sample (K-sed-2). The total PAH concentration in the Anglin Bay sediments is 16.2 ug/g while in Lake Ontario the total PAH equals 3.8 ug/g. The PAH in the sediments are made up of the more strongly adsorbed PAH (i.e., benzo(a)pyrene, benz(a)anthracene, fluoranthene). The more soluble components of PAH, if present in the sediments, would likely be leached into the surface water. While the concentration of PAH in the Anglin Bay sediments are higher than in Lake Ontario it is difficult to determine if these elevated levels indicate contamination from coal tar or result from other sources. It is possible that other sources such as storm water runoff, fallout from air emissions (i.e., furnace, fireplace, automobiles), or recreational use (i.e., boating) may contribute to the PAH loading in the Bay. Based on a single, one point sampling it is impossible to determine the nature of the PAH contamination in Anglin Bay but these low levels are likely representative of background concentrations for sediments in an urban environment. The Lake Ontario sediments are considered to be at background levels for PAH.

TABLE 3.3 ANALYTICAL RESULTS FOR SEDIMENT SAMPLES

CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOIL

ug/g

COMPOUND	K-SED -1	K-SED -2	MDL	Lab Blank	MDL
ACENAPHTHENE	0.3	-	0.2	-	0.02
ACENAPHTHYLENE	-	-	0.2	-	0.02
ANTHRACENE	0.7	-	0.2	-	0.02
BENZ(A)ANTHRACENE	1.3	-	0.2	-	0.02
BENZO(B) + BENZO(K)FLUORANTHENE	1.8	0.9	0.2	-	0.02
BENZO(A)PYRENE	1.5	0.5	0.2	-	0.02
BENZO(GHI)PERYLENE	1	-	0.4	-	0.04
CHRYSENE	1.4	0.7	0.2	-	0.02
DIBENZ(A,H)ANTHRACENE	-	-	0.4	-	0.04
FLUORANTHENE	1.8	0.8	0.2	-	0.02
FLUORENE	0.4	-	0.2	-	0.02
INDENO(1,2,3-CD)PYRENE	0.8	-	0.4	-	0.04
NAPHTHALENE	-	-	0.2	0.04	0.02
PHENANTHRENE	2.2	0.2	0.2	-	0.02
PYRENE	3	0.7	0.2		0.02

MDL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS

(%)

COMPOUND	K-SED -1	K-SED -2	Lab Blank
D8-NAPHTHALENE	18	26.8	51.3
D10-ANTHRACENE	70.1	54.9	74.6
D10-FLUORANTHENE	67.5	72.5	70.3
D12-PERYLENE	84.3	100	61.6

* = Recovery not determined due to necessary dilution of extract.

TABLE 3.4 ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES

CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN WATER

ppb

COMPOUND	K-SURF -1	K-SURF -2	K-SURF -3	Lab Blank	MDL
ACENAPHTHENE	-	-	-	-	0.05
ACENAPHTHYLENE	-	-	-	-	0.05
ANTHRACENE	-	-	-	-	0.05
BENZ(A)ANTHRACENE	-	-	-	-	0.05
BENZO(B) + BENZO(K)FLUORANTHENE	-	-	-	-	0.05
BENZO(A)PYRENE	-	-	-	-	0.05
BENZO(GHI)PERYLENE	-	-	-	-	0.1
CHRYSENE	-	-	-	-	0.05
DIBENZ(A,H)ANTHRACENE	-	-	-	-	0.1
FLUORANTHENE	-	-	-	-	0.05
FLUORENE	-	-	-	-	0.05
INDENO(1,2,3-CD)PYRENE	-	-	-	-	0.1
NAPHTHALENE	-	-	-	-	0.05
PHENANTHRENE	-	-	-	-	0.05
PYRENE	-	-	-	-	0.05

MDL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS

(%)

COMPOUND	K-SURF -1	K-SURF -2	K-SURF -3	Lab Blank
D8-NAPHTHALENE	66.3	67.1	68.7	67.6
D10-ANTHRACENE	90.4	85.6	96.3	93
D10-FLUORANTHENE	80	83.1	84.8	81.9
D12-PERYLENE	83.1	83.4	98.2	100

The results of trace metals concentrations (Appendix D) in the sediments are consistent with, although slightly lower than, previous samples collected by MOE (1985). The results for trace metals in the sediments are typical of sediments in an urban environment.

The PAH concentrations for the surface water samples (Table 3.4) were all non-detectable indicating that if coal tar waste or contaminated groundwater was discharging to the surface waters they are not having a measurable impact on the general water quality.

Inorganic parameters (Appendix D) did not indicate elevated levels of any parameters in the surface waters and both samples were consistent with the background sample collected from the LaSalle Causeway Bridge.

3.3.4 Building Sump Quality

During the inspection of the building sumps a slight odour of coal tar was detected in the main sump of the police station. All other sumps were free of odours. The police station sump is located in the boiler room in the southwest corner of the building and when the cover was lifted off the sump there was a slight but noticeable coal tar odour coming from the sump pit. The sump pit has two pipes discharging into it, one from the west side and one from the north. Water was flowing into the sump from both pipes at a total rate of about 90 - 180 L/min. The sump pump was running continually during the sampling and was discharging the water to the sanitary sewer. Water samples were collected from each of the pipes discharging in the sump and analyzed for PAH only.

The analytical results for the two samples are given in Table 3.5. Both samples have low level concentrations of PAH with total PAH concentrations of about 13 ppb. The PAH compounds present

TABLE 3.5 ANALYTICAL RESULTS FOR BUILDING SUMP SAMPLES

CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN WATER

ppb

COMPOUND	SUMP west	SUMP north	Lab Blank	MDL
ACENAPHTHENE	8.3	9.5	-	0.05
ACENAPHTHYLENE	1	1.1	-	0.05
ANTHRACENE	0.1	0.2	-	0.05
BENZ(A)ANTHRACENE	0.06	0.05	-	0.05
BENZO(B)FLUORANTHENE				
BENZO(K)FLUORANTHENE	-	-	-	0.05
BENZO(A)PYRENE	-	-	-	0.05
BENZO(GHI)PERYLENE	-	-	-	0.1
CHRYSENE	TR	TR	-	0.05
DIBENZ(A,H)ANTHRACENE	-	-	-	0.1
FLUORANTHENE	0.9	0.9	-	0.05
FLUORENE	0.1	0.8	-	0.05
INDENO(1,2,3-CD)PYRENE	-	-	-	0.1
NAPHTHALENE	1.5	-	-	0.05
PHENANTHRENE	0.2	0.5	-	0.05
PYRENE	1.1	1.1	-	0.05

MDL = METHOD DETECTION LIMIT
TR = TRACE

Total concentration of benzo(b)- and benzo(k)fluoranthene is shown in the row for benzo(k)fluoranthene.

RECOVERY OF SURROGATE STANDARDS
(%)

COMPOUND			Lab Blank
D8-NAPHTHALENE	53.2	52.7	47
D10-ANTHRACENE	92.7	100	89.9
D10-FLUORANTHENE	79.9	78.2	81.9
D12-PERYLENE	74.2	71.8	87.1

in the samples are the more soluble PAH with acenaphthene at the highest concentrations. The heavier molecular weight PAH compounds were generally not detected in the sump samples.

The sump samples indicate that contaminated groundwater is entering the foundation drains. The foundation drains which are probably laid around the perimeter of or beneath the building will collect the groundwater in the proximity of the building. Because the monitoring wells adjacent to the building (i.e., K3A, K1A and K1B) are contaminated it is expected that the building foundation drains will also collect contaminated groundwater. The monitoring wells adjacent to the building have much higher concentrations than the sump samples. In the building sump, continual flushing has likely removed most of the free tar in the foundation drains and therefore the water discharging to the sump will only contain the more soluble PAH.

3.4 WASTE SOURCE AREAS

3.4.1 Waste Source Identification

Based on all of the site investigations including:

- Historical Review
- Radar Survey
- Soil Gas Sampling
- Drilling and Soil Sampling
- Groundwater Sampling

it is possible to define waste source areas on the former Kingston gas plant site and to provide an indication of the extent of contamination.

The waste sources are defined primarily on the historical review simply because most of the potential sources could not be adequately explored due to the presence of buildings constructed in these locations.

The following paragraphs, in association with Figure 3.10, and Figures 3.1 and 3.2 identify and describe the potential sources of on-site coal tar wastes.

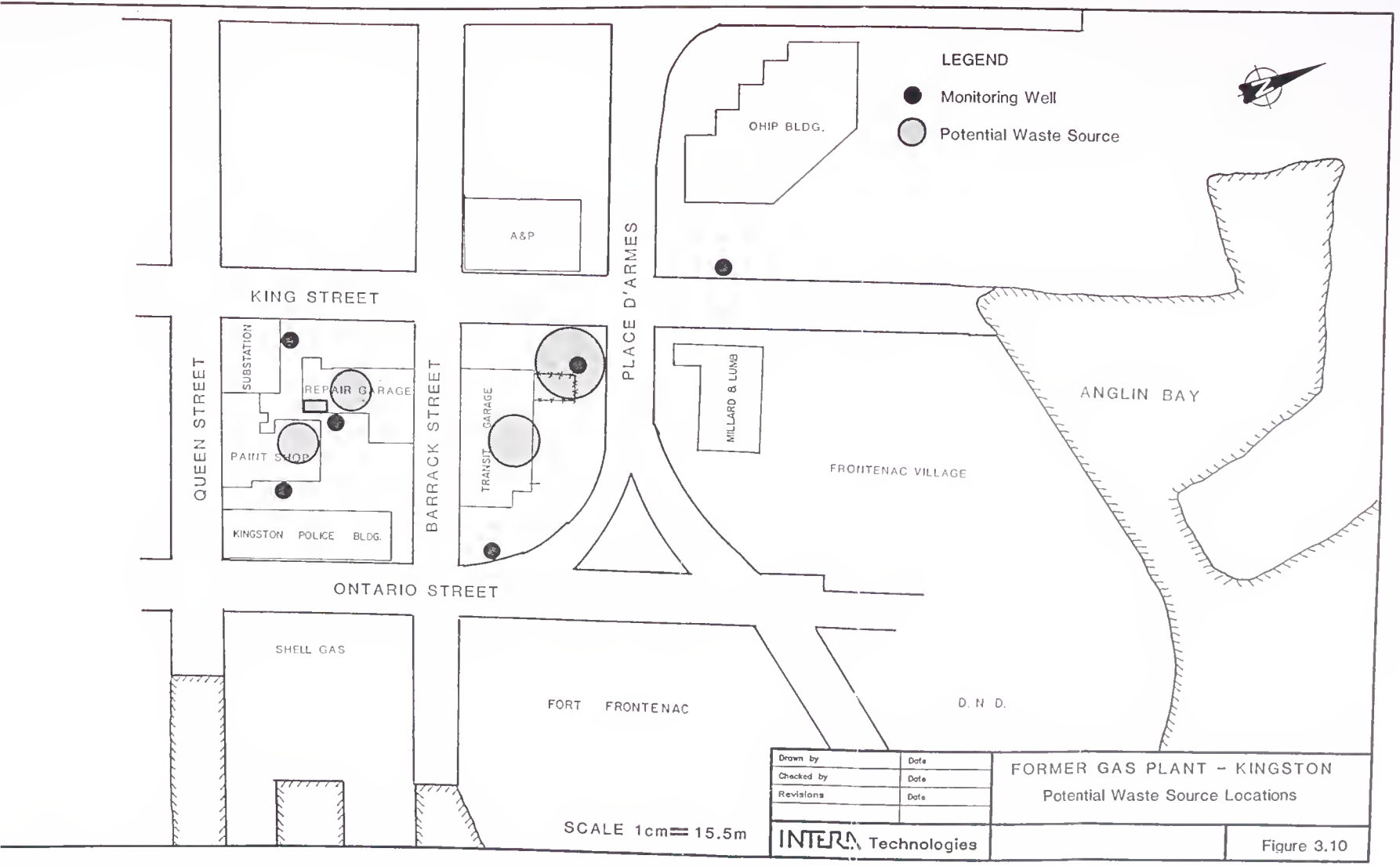
Relief Gas Holder - PUC Paint Shop

The relief gas holder, located in the PUC paint shop was likely the first gas holder constructed on the site. The relief gas holder would have been used to store raw gas prior to cleaning and therefore might contain tar residue on its base. The outline of the gas holder is still apparent in the floor of the garage. Evidence of coal tar waste as determined by soil gas sampling has been found on the surface of the tank, and on both the north and south side of the building. Obvious tar was found on the soil gas probe in a test hole south of the gas holder.

The gas holder in the PUC paint garage is considered to be a definite source of coal tar on the property.

Relief Gas Holder - PUC Repair Garage

The relief gas holder, located under the PUC repair garage was likely used as a main gas holder in association with the gas holder in the paint garage and as a relief gas holder in association with the smaller gas holder in the Barrack-Place D'Armes block. There is no obvious evidence of the location of the gas holder. The repair garage has had hydraulic hoists and electrical lines installed into the floor of the garage and therefore the floor area could not be probed for evidence of coal tar wastes. It is not known if wastes were encountered during the installation of the hydraulic hoists. Soil gas holes adjacent and to the east of the building did not detect organic


LEGEND
Monitoring Well
Potential Waste Source
OHIP BLDG.
A&P
KING STREET
PLACE D'ARMES
QUEEN STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
KINGSTON POLICE BLDG.
BARRACK STREET
TRANSIT GARAGE
MILLARD & LUMB
FRONTENAC VILLAGE
ANGLIN BAY
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D. N. D.
SCALE 1cm = 15.5m
Drawn by
Date
Checked by
Date
Revisions
Date
INTERA Technologies
FORMER GAS PLANT - KINGSTON
Potential Waste Source Locations
Figure 3.10

vapours or other evidence of coal tar wastes. The monitoring well K5A located in the same area had obvious indications of coal tar in the bedrock and had the highest PAH concentrations of all sampled wells.

Although there is no physical evidence to indicate coal tar waste in this area the gas holder is considered to be a likely source.

Condenser House - PUC Repair Garage/Office

The condenser house was located in the area of the PUC office adjacent to the repair garage. The condenser house would have contained the tar wells and tar tanks. Historical maps did not show exact locations of the tar tanks but this area is the most likely location. The site investigations did not reveal any evidence of the tar tanks or tar wells but the area could not be adequately explored because of the present land use.

The area of the condenser house can not be shown to contain the tar tanks but this area is suspected as a possible source of coal tar wastes.

Relief Gas Holder - PUC Bus Transit Garage

The large relief gas holder located in the Barrack - Place D'Armes block was initially a main gas holding tank used in association with the smaller relief gas holders. When the large main gas holder was constructed on the corner of King and Place D'Armes the gas holder would have been converted to a relief tank. As a relief gas holder it would have contained raw gas prior to cleaning and therefore the base of the tank may contain tar wastes. The gas holder is now covered by the PUC bus transit garage and was identified in the radar survey. The gas holder was explored in its center using a soil gas test hole which did not detect high concentrations of organic vapours. Borehole K1 located east of the gas holder intersected free coal tar during the drilling and monitoring well K1B was found to contain free tar.

The relief gas holder is considered to be a likely source of coal tar waste based primarily on its historical use, the radar survey, and evidence of free tar in the shallow well at K1.

Main Gas Holder - Corner King and D'Arnes

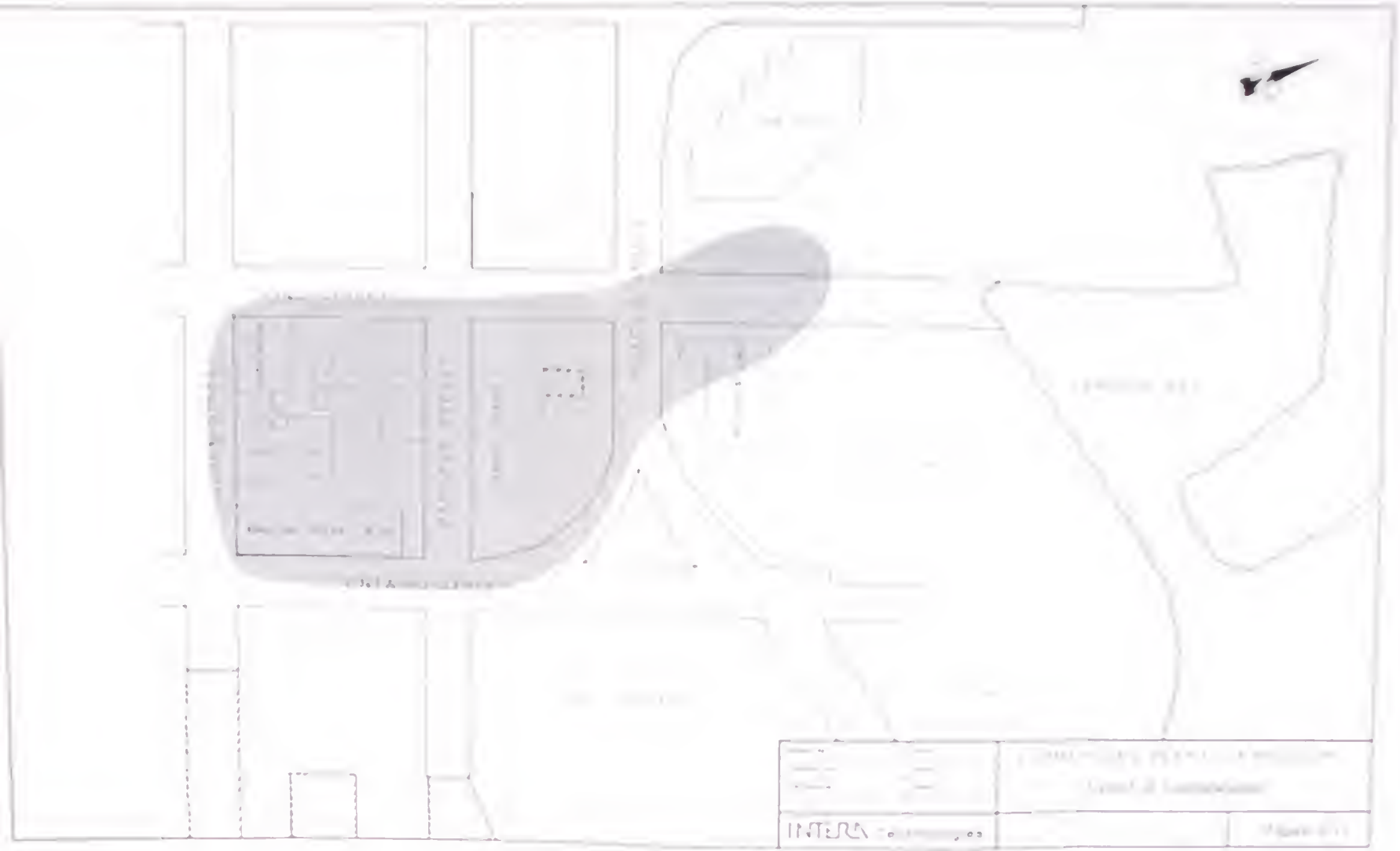
The main gas holder is located on the corner of King and Place D'Arnes in what is now a gravel parking lot. The perimeter wall is visible in several locations in the parking lot. During drilling of borehole K2 approximate 60 cm of free tar was found at the bottom of the tank.

Based on the thickness of tar on the bottom of the tank and the large diameter of the tank the main gas holder is considered to be a major source of coal tar waste on the gas plant property.

3.4.2 Extent of Contamination

Each of the boreholes drilled on-site and the one off-site borehole encountered coal tar waste and contaminated groundwater. The on-site boreholes were located at the four corners and the centre of the original gas plant and therefore the entire property is considered to contain coal tar wastes. The one off-site borehole confirms that wastes have migrated off-site. With coal tar wastes at the four corners of the site it is also likely that coal tar waste and/or contaminated groundwater are migrating off-site in other locations as well. Because all of the boreholes encountered coal tar, the extent of contamination can not be accurately defined. As a minimum the extent of contamination includes the two block area containing the gas plant property as indicated in Figure 3.11 but the outer limit is presently unknown.

INTERN



Evidence of coal tar contamination as reported in 1986 was not found in the area of the storm sewer excavation on King Street, north of Place D'Armes. Borehole K6 located in this area did not find coal tar in the shallow overburden where the storm sewer is located but only in the bedrock. A soil gas test hole adjacent to the sewer line found background levels of organic vapours in the soil. In the inspection of the only storm sewer manhole in the area odours or evidence of coal tar seepage were not detected. The sediment sample collected in the area of the sewer outfall in Anglin Bay had low level concentrations of PAH but the source of the PAH can not be definitely attributed to the gas plant. In summary, there is no evidence to confirm that coal tar contamination was present in the storm sewer excavation. Based of the geology of borehole K6 which contains clay and clay till in the overburden it is unlikely that if tar was found in this area it migrated through the soil. It is possible that the excavated tar was disposed in this area during the operation of the plant and is of limited extent.

Off-site migration of coal tar and contaminated groundwater may be affected by the following factors:

- Dip of bedding planes;
- Orientation of joints;
- Influence of the sanitary trunk sewer;
- Influence of the police station sump.

The dip of the bedding planes is likely towards the south - southwest. Free coal tar may migrate off-site in this direction by gravity flow along the bedding planes. The rate of migration and the extent of contamination will depend on a number of factors including the volume of source material, the aperture and continuity of the bedding planes, and the magnitude of the gravity gradient.

Similarly, off-site migration may occur preferentially in the direction of major joint sets. With four major joint sets in the bedrock, it is difficult to predict which set will have the greatest influence for off-site migration. Factors such as joint spacing, continuity and aperture will control the migration direction.

The sanitary trunk sewer which runs along Ontario Street and up Place D'Armes may act as an interceptor for tar migration because of its depth in the bedrock. The invert elevation of the trunk sewer is typically at about 72.56 m ASL or about 6 m below ground. At this depth, it is below the zones of contamination found in several boreholes. In borehole K1 adjacent to the trunk sewer coal tar contamination including free tar was found from about 3 to 6 m below surface. If the free tar is migrating towards the trunk sewer it will collect in the bedding material surrounding the sewer which is more permeable than the rock itself. If sufficient tar accumulates in the bedding material the tar may migrate along the bedding material in the downhill direction. The flow in the sewer is directed north along Ontario Street and then west along Place D'Armes and therefore tar migration may occur in the same direction. It is also possible that tar will simply collect in the bedding material and then migrate out the other side of the bedding material back into the bedrock if the bedrock is sufficiently permeable. Migration along the sewer bedding material however is more likely to occur.

If the trunk sewer is collecting tar and migration along the sewer bedding material is occurring this may account for the off-site contamination in monitoring well K6A. In the area of King and Place D'Armes the trunk sewer comes out of the bedrock (i.e., depth to bedrock increases) and the tar may be migrating down gradient along the bedrock surface towards K6.

The influence of the police station sump may have a positive affect on off-site migration in that the sump and foundation drains will collect contaminated groundwater and possibly free tar.

Groundwater flow is directed towards the sump because it is the low point in the groundwater system. The collected groundwater which has low level PAH contamination is disposed to a sanitary sewer. There was no evidence of free tar in the sump but it is possible that tar is collecting under the building and thereby not migrating off-site.

4. ENVIRONMENTAL IMPACT ASSESSMENT

With coal tar wastes identified on-site there is a potential for environmental impact. The environmental impact can be assessed based on the potential to cause detrimental effects on human health or the environment. The potential for environmental impacts can be considered based on the following:

- direct contact with waste materials;
- air emissions or air quality impacts;
- groundwater quality impacts;
- surface water quality impacts.

Direct contact with the coal tar waste materials can only occur if the waste is exposed at surface. At present all of the waste is below surface and primarily contained in the bedrock and therefore direct contact with the waste is unlikely to occur. There is a possibility that tar wastes may seep into sewers or manholes and contact with utility workers may occur but the inspection of the sewer manholes did not identify odour or seepage problems at the time of the inspections. Similarly seepage of tar into the basement of the police station or into the building sump is also a possibility but again inspections of the building did not identify this as a problem at the time of inspection. Because the sump is collecting contaminated groundwater, it is possible that maintenance workers may, occasionally, be in direct contact with the contaminated water or air. The levels of contamination in the water however are low and occasional contact with the water (other than for drinking) are unlikely to cause adverse health effects. If the coal tar waste was exposed at surface during construction or redevelopment of the gas plant property the potential for direct contact will increase significantly and adverse health effects may occur.

Impacts on air quality due to buried coal tar wastes are not apparent at the present time. There are no detectable odours or air

emissions associated with the buried waste except in the sump of the police station. The odours from the sump water are only detectable in the immediate area of the sump when the sump cover is removed. Impacts on the ambient air quality in the boiler room are unlikely to be affected by the odours in the sump providing the sump cover remains in place because the boiler room is well ventilated with open vents to the outside.

Significant impacts on air quality may occur if coal tar waste is exposed at surface during potential construction or redevelopment of the property.

The groundwater quality in the area of the former gas plant has been impacted by the coal tar waste. Several organic contaminants such as benzene and phenols at concentration levels of up to 65,000 and 40 ppb respectively are found in the groundwater at concentrations that exceed Canadian drinking water guidelines (i.e. 5 ppb for benzene and 2 ppb for phenols) and MOE water quality guidelines (i.e. 250 ppb for benzene and 1 ppb for phenols). Free coal tar as a separate phase is also present in the groundwater. Impacts on human health are limited by the fact that the groundwater in the area is not used as a water supply. The police station sump is discharging groundwater to the sewer and it is possible that there are other sumps off-site that have not been identified in the area.

Impacts on surface water quality were not measured by this study. It is possible that contaminated groundwater and/or free tar may be discharging to Anglin Bay or Lake Ontario but a more detailed study of off-site contamination, which was outside the terms of reference of this study, is required before the degree of environmental impact on the surface water can be determined. Preliminary samplings indicates that PAH are not present in the surface waters of Anglin Bay or Lake Ontario. Sediment sampling from Anglin Bay and Lake Ontario indicate low levels of PAH in the sediments but it is inconclusive as to the source of the PAH.

5. RECOMMENDATIONS

The initial site investigations of the Kingston Gas Plant have identified coal tar contamination in the area bounded by Queen, Ontario, Place D'Armes and King Streets. Based on this conclusion it is recommended that additional investigations be conducted outside of this area to define the extent of contamination and the potential impacts on groundwater and surface water in the off-site areas. The detailed investigations should include the following:

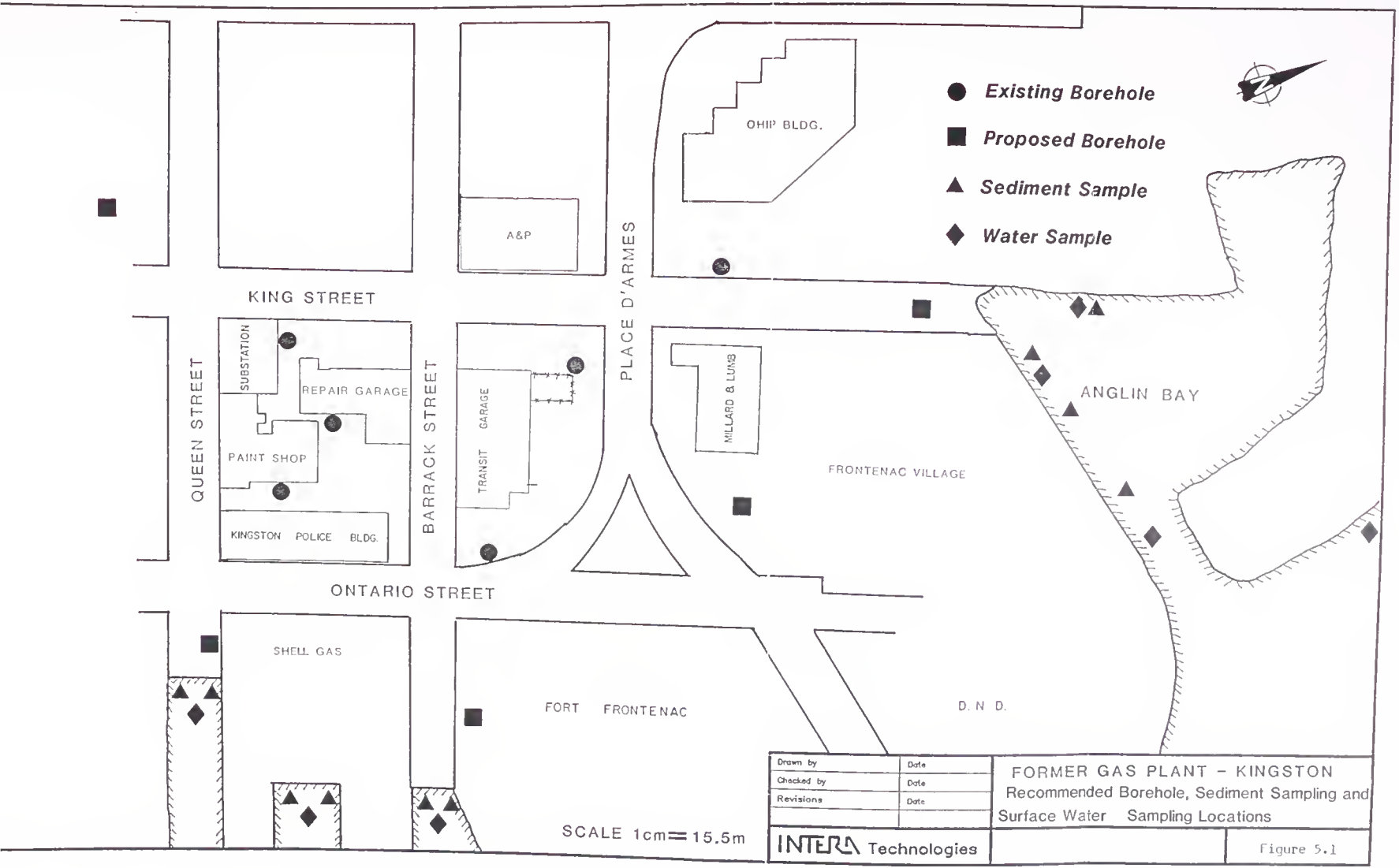
- Drilling of additional boreholes and the installation of monitoring wells (Figure 5.1) in off-site areas to define extent of contamination particularly between the gas plant site and Anglin Bay and Lake Ontario.

- Sampling of all monitoring wells (new and existing) and analysis of samples for contamination indicator parameters such as PAH (i.e. naphthalene and benzo(a)pyrene), benzene, toluene, xylene and phenols;

- Inspection of sumps in off-site buildings

It is possible that free coal tar and aqueous phase contaminants are migrating to Anglin Bay or Lake Ontario. More detail investigations of the surface waters are required to evaluate the degree of environmental impact. It is recommended that the following investigations be completed:

- An inspection of bottom sediments of Anglin Bay and the harbors in Lake Ontario should be completed to determine if visible tar is present in the sediments;


Existing Borehole
Proposed Borehole
Sediment Sample
Water Sample
OHIP BLDG.
A&P
KING STREET
QUEEN STREET
SUBSTATION
REPAIR GARAGE
PAINT SHOP
KINGSTON POLICE BLDG.
BARRACK STREET
TRANSIT GARAGE
PLACE D'ARMES
MILLARD & LUNB
FRONTENAC VILLAGE
ANGLIN BAY
ONTARIO STREET
SHELL GAS
FORT FRONTENAC
D. N. D.
SCALE 1cm = 15.5m
Drawn by
Date
Checked by
Date
Revisions
Date
INTERA Technologies
FORMER GAS PLANT - KINGSTON
Recommended Borehole, Sediment Sampling and Surface Water Sampling Locations
Figure 5.1

- The bottom sediments should be sampled with the collection of samples from Anglin Bay, samples each from the harbors in Lake Ontario and one sample from a background location (Figure 5.1);

- Sediment samples should be analyzed for contaminant indicator parameters such as PAH (i.e. naphthalene, benzo(a)pyrene), trace metals, and cyanide;

- Surface water samples (Figure 5.1) should be collected from Anglin Bay and each of the harbors and Lake Ontario and analyzed for contaminant indicator parameters such as PAH, benzene, toluene, xylene, phenols and trace metals.

Coal tar and contaminated groundwaters have been found on the former gas plant property. At present, the buried waste or contaminated groundwater does not present a health hazard to users of the property. However, if construction or redevelopment of the property is planned then the potential for exposure may increase. It is recommended that any construction or redevelopment in the area of the former gas plant that disturbs the subsurface be completed with caution and only with the direction of the Ministry of the Environment.

Groundwater entering the building sump in the police station was found to contain trace levels of PAH. The contamination is presently at low levels and is being disposed to the sanitary sewer. The following are recommendations for this problem:

- the sump water be sampled twice yearly (spring and fall) and the samples analyzed for PAH, benzene, toluene, xylene and phenols in order to provide monitoring of the contamination levels.

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1865 - fortification survey (Public Archives Canada, NMC 21076, 2/2);
1875 - bird's eye view (Public Archives Canada, NMC 22439) blow up;
1908 - fire insurance plan (Kingston Public Utilities Commission)
1911 - revision of 1908 fire insurance plans (Public Archives Canada, NMC 10707, 5/49 main site; 22/49 auxiliary gas holder)
1924 - fire insurance plan (Kingston Public Utilities Commission)
1928 - block plan of land and buildings owned by Commission (Kingston Public Utilities Commission)
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Air Photographs

1954, National Air Photo Library No. A13968-44
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Geotechnical Reports

City of Kingston Work's Department - Sewer Maps

1) Place D'Armes - Intercepting Sewer, A263-1

2) Ontario St. - Place D'Armes to Causeway, A318

3) Ontario St. - Intercepting Sewer

4) Queen St. - Ontario St. Easterly, A-352

5) King St. - Place D'Armes, A-332

6) King St. and Wellington St., A-269

7) Queen St. - Ontario St. to King St.

City of Kingston, Police Headquarters, Chector, Barbacki, Forte and Associates 1970 Column Schedule and Test Pits

APPENDIX A

Terms of Reference

INITIAL STUDIES

OF SELECTED COAL GASIFICATION WASTE SITES

IN SOUTHEASTERN ONTARIO:

KINGSTON AND NAPANEE

MINISTRY OF THE ENVIRONMENT

SCHEDULE 1

REQUEST FOR PROPOSAL

SEPTEMBER 1987

SCHEDULE 1

REQUEST FOR PROPOSAL

1.0 BACKGROUND

The Ontario Ministry of the Environment has recently completed an Inventory of Coal Gasification Plant Waste Sites in Ontario where coal gas was produced for municipal consumption. The study revealed a total of 41 sites.

At some of these sites, coal tar wastes have already been found and work is in progress. At the remaining sites, little or nothing is known about the presence of wastes. This Request for Proposals (R.F.P.) is for studies at two sites to determine if wastes are present. at each site, how they occur, to obtain an indication of their extent on the site, and the likelihood of off-site occurrence. The two selected sites are: Kingston and Napanee. A separate proposal is required for each site.

All detailed work at these two sites is to be confined to the old gasification plant site, although some cursory investigation may be necessary off-site.

2.0 CONSULTING ASSIGNMENT

2.1 Objectives

The Ministry requires a study to meet the following objectives:

i) at each site, determine whether or not coal gasification plant wastes are present;

ii) if present, determine how these wastes occur on site (in storage tanks, in soil, etc.), and obtain some indication of their distribution;

iii) if present, determine whether the wastes are contained, or whether the wastes, or contaminated water, or both, may be moving off-site.

iv) if present, determine whether or not the wastes are impacting on, or pose an imminent threat of impact on, human health and safety, or the environment, or both.

To meet these objectives, the study will be completed in two phases. The scope of work to be completed in each phase is summarized below.

2.2 SCOPE

Phase 1 Surface Investigations

Prior to the commencement of any work on site, the Ministry will notify the property owner of the planned study. The consultant will be responsible for obtaining permission from the property owner to complete the necessary work on site.

Proceeding from the available information in the Inventory of Coal Gasification Plant Waste Sites in Ontario, Volumes I and II, Phase 1 will involve searching for any buried wastes using visual, olfactory and geophysical techniques. All possible underground waste storage locations must be investigated in Phase 2 to determine the contents of any storage vessels remaining underground, and the presence or absence of any coal tar contamination in the soils adjacent to the locations of former storage vessels. If test drilling, test pitting and ground water and soil sampling are necessary, Phase 1 will include the selection of initial sites for this work.

Phase 2 Drilling and Sampling

Prior to commencing work that would disturb any wastes or open any waste containers at a site, background measurements of airborne PAH's should be taken. Distinction should be made between contributions to airborne PAH's coming from non coal tar sources and any coming from existing undisturbed coal tar sources on site.

Real time measurements of airborne hydrocarbons are possible in the field using such instruments as photo-ionization detectors and portable gas chromatographs. They have proven useful to indicate the presence of benzene, toluene, xylene and naphthalene in the air. Although these four hydrocarbon compounds are not PAH's, they are generally present with coal tars. Air quality protection standards or provisional guidelines for these four compounds as well as benzo (a) pyrene are available. (See Table 1.)

After the exposure of coal tar wastes has commenced, a field meter should be used not only as an indicator of coal tar wastes, but also to alert people on-site when to use respirators and other protective equipment. The health and safety protocols, as specified in Schedule 2 item 12.3, must be followed. Appropriate measures should be taken to protect the ambient air quality during work at each site.

TABLE 1

AIR QUALITY PROTECTION PARAMETERS[1])

Hydrocarbon Compound	Concentration in ng/m^3 Averaged Over 0.5 Hours	Limiting Effect, Type of Standard
Benzo (a) pyrene	3.3	Health, Provisional Guideline at Point of Impingement Single Source
Benzene	10,000	Health, Standard at Point of Impingement
Toluene	2,000	Odour, Standard
Xylene	2,300	Odour, Standard
Naphthalene	36	Health, Provisional Guideline

[1]) Air Resources Branch, M.O.E., as of 87-05-26.

Based on the assessment of data from Phase 1, Phase 2 is to obtain soil, ground water and surface water samples necessary to confirm whether or not coal tar wastes and derived contamination are present at the site. If they are, Phase 2 is also to obtain an indication of their extent and whether or not they may be moving off-site. All excavations, both drilled and dug, should be sampled and logged continuously with depth. Any dug pits or trenches should be sampled at horizontal intervals no greater than 5 metres. The depth explored should take into account the heavier-than-water seepage character of most coal tar fractions.

Unless previous evidence indicates conclusively that there is no existence of wastes on site, test holes should be drilled and sampled at least along the site boundaries. The soil around all inhabited buildings must be checked. A temporary monitoring well should be installed in each of the test holes to indicate ground water levels and quality.

Sewer beddings and other buried utility lines are potential conduits for collection and migration of contaminants. All on-site utility lines should be

entering storm sewers, the sewer water and sediments must be sampled.

If wastes can be seen in soils at the site boundaries, then they will be considered likely to be moving off-site. No detailed work is required off-site for this study, unless the wastes or derived contamination pose a risk of imminent impact on human health and safety. If so, the likely extent of this impact should be reported immediately to the Ministry.

If no wastes are seen in the soils, but it is suspected that contaminated ground water may be moving off-site and threatening existing or anticipated ground water supplies, then monitoring wells should be installed and sampled to remove this uncertainty.

To obtain a first approximation of the extent of coal tar contamination, visual and olfactory evidence can be used. However, where there is reasonable doubt as to whether the type of tar contamination is of coal or petroleum origin, laboratory analysis of selected generic samples is required to enable distinction. The criteria for distinction must be specified. To determine the level of ground water contamination, the hydrochemistry parameters listed in Table 2 should be considered as basic. Others may be added by the consultant, but costs must be kept to a minimum.

TABLE 2. HYDROCHEMISTRY PARAMETERS

pH

Calcium
Magnesium
Sodium
Potassium

Trace Metals

Alkalinity
Bicarbonate
Sulphate
Sulphide
Chloride
Cyanide
Ammonium
TKN
COD
TOC
Phenols

Volatiles:

Benzene
Toluene
Naphthalene

PAHs:

Benzo (a) Pyrene

In addition to the above objectives and scope applying at all sites, the following site-specific questions must be answered:

- At the Kingston site, what is the type and extent of the tar contamination that was found in a sewer excavation in 1986 on King Street north of Place d'Armes Street? Is contamination from this area likely to reach Lake Ontario?

South of Barrack Street on the Kingston site where two gas holders were located, a cracking wall and a sloping floor slab suggest hazards of structural instability and toxic vapours may be present. Appropriate safety measures must be taken throughout the study as stipulated in Schedule 2.

° Future plans for the Napanee site vicinity include excavations for bank stabilization along the Napanee River and the construction of a boat ramp at the site. Are there any coal tar wastes along the river bank, and could the excavation activities cause them to enter the river? Do coal tar wastes occur in the Napanee River sediments? Is contaminated ground water discharging into the river? Regarding the safety of inhabited buildings in the site vicinity, could possible underground coal tar wastes or contaminated ground water or fumes enter the welding shop, the Odd Fellows Hall, or the home for senior citizens? Do coal tar wastes occur near the Center Street bridge as suggested in the inventory report identified earlier?

Following the completion of on-site work at each site, the consultant will be responsible for restoring the site to its original condition to the proprety owner's satisfaction.

At the end of Phase 2, and prior to report preparation, a meeting will be held to review the results and confirm the content and organization of each final report. Additional meetings required during the course of the study will be arranged as the need arises.

2.3 REPORTING

The results of the study will be documented in a separate report for each site. Each report will contain, among other things:

° A base map showing the location of the site.

° A site plan for the site showing:

i) all waste prospects identified from such sources as plant layouts, visual and olfactory evidence and geophysical evidence;

ii) locations of test holes, pits, trenches and monitor wells;

iii) confirmed locations of wastes from visual evidence, soil sampling and ground water sampling; and

iv) delineation of the extent of the wastes, (showing whether or not they are confined to the site).

° A geologic log for each test hole, pit and trench. Geologic logs of pits and trenches should be taken at lateral intervals of no more than 5 metres along the excavation.

- A construction diagram for each monitor well, including the elevation of its measuring point relative to the other monitor wells and pertinent features.

- Tables showing the parameters for which laboratory analyses were performed on soil and water samples, and the analysis results.

- A discussion of what investigative work was done, what was found, and recommendations for what further detailed studies and remedial work might be necessary.

During all phases of the study, the consultant will be responsible for providing verbal status reports to Ulo Sibul at (416) 323-5182.

Thirty copies of the final report are required.

3.0 CONTENT OF THE PROPOSALS

Each proposal should contain, among other things,

- Specific discussions of study methods and procedures to be used in the study, including geophysical methods, air quality monitoring methods, drilling methods, monitoring well construction methods, soil and ground water sampling, preserving and laboratory analysis methods. The laboratory to be used for soil and water samples must be identified. The Ministry laboratory is not available. The laboratory criteria to be used to distinguish coal tar contamination from petroleum contamination must be identified.

- A description of the protocols to be followed to preserve and protect the health and safety of workers and the public consistent with the Ministry of Labour requirements and the Occupational Health and Safety Act.

- A description of the role of each member of the study team, including subcontractors. Curriculum Vitae and summaries of relevant experience should be included. Relevant company experience of both the main contractor and any subcontractors is also required. Note that team members specified in each proposal will be expected to participate throughout the study.

Substitutions to those named to the initial study team are not acceptable without the prior approval of the Ministry of the Environment.

realistically achievable. In setting up this schedule, please note that the Ministry considers the assessment of buried coal gasification plant wastes a high priority and wants to see the study expedited accordingly.

- A listing of per diem (not hourly) rates for each member of the study team, charging practices for travel and out-of-pocket expenses, supplies, word processing, graphics, printing, etc.

- A detailed outline of proposed costs for each phase of work, including allotted man-days per team member.

- The estimated total cost of the complete assignment. The estimated total cost of the assignment is to include all miscellaneous costs, as well as allowances for normal potential extra costs.

- Acknowledgement of the Letter of Agreement (attached) which must be signed prior to letting of the contract. Proposals must indicate acceptance of the agreement or clearly state items that are unacceptable and suggested modifications.

While the study approach, phasing and reporting outlined in this RFP represent the views of the Ministry, modifications or changes suggested with justification by the consultants will certainly be considered.

4.0 SUBMISSION AND EVALUATION OF PROPOSALS

The written proposals will serve as the basis for the selection of a consultant to conduct the studies. A bidder's meeting will be held on MONDAY OCT. 19th, 1987 at 11:00 A.m in the 6th Floor Boardroom at ~~40~~ St. Clair Avenue West, Toronto, during which the studies will be discussed.

Proposals should be directed to:

Purchasing Office
The Ontario Ministry of the Environment
5th Floor, 135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

Deadline for their receipt is MONDAY OCT. 26th, 1987 at 3:00 P.m. Please submit five copies for each site to help us expedite proposal evaluation.

Proposals will be evaluated according to the following criteria:

1. Thoroughness, clarity and completeness.

2. Study approach and methodology.

3. Previous experience, qualifications and expertise of the members of the proposed study team.

4. Where applicable, previous performance on Ministry contracts.

5. Time frame.

6. Where two or more proposals satisfactorily meet the preceeding criteria, the cost given in the proposals will be taken into consideration in selecting the successful bidder. The Ministry of the Environment reserves the right not to select the lowest bidder.

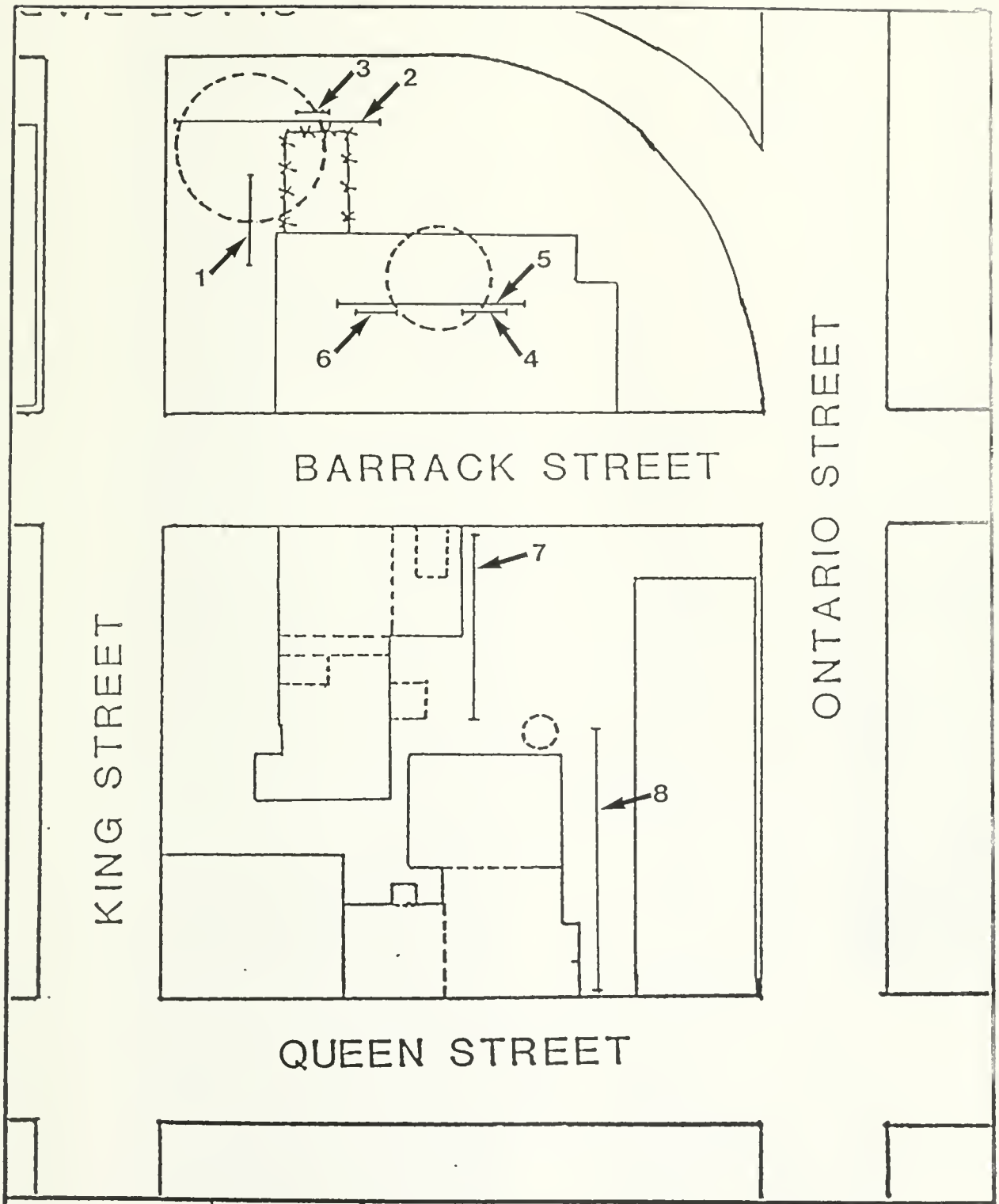
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September 8, 1987
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APPENDIX B

Ground Probing Radar Survey



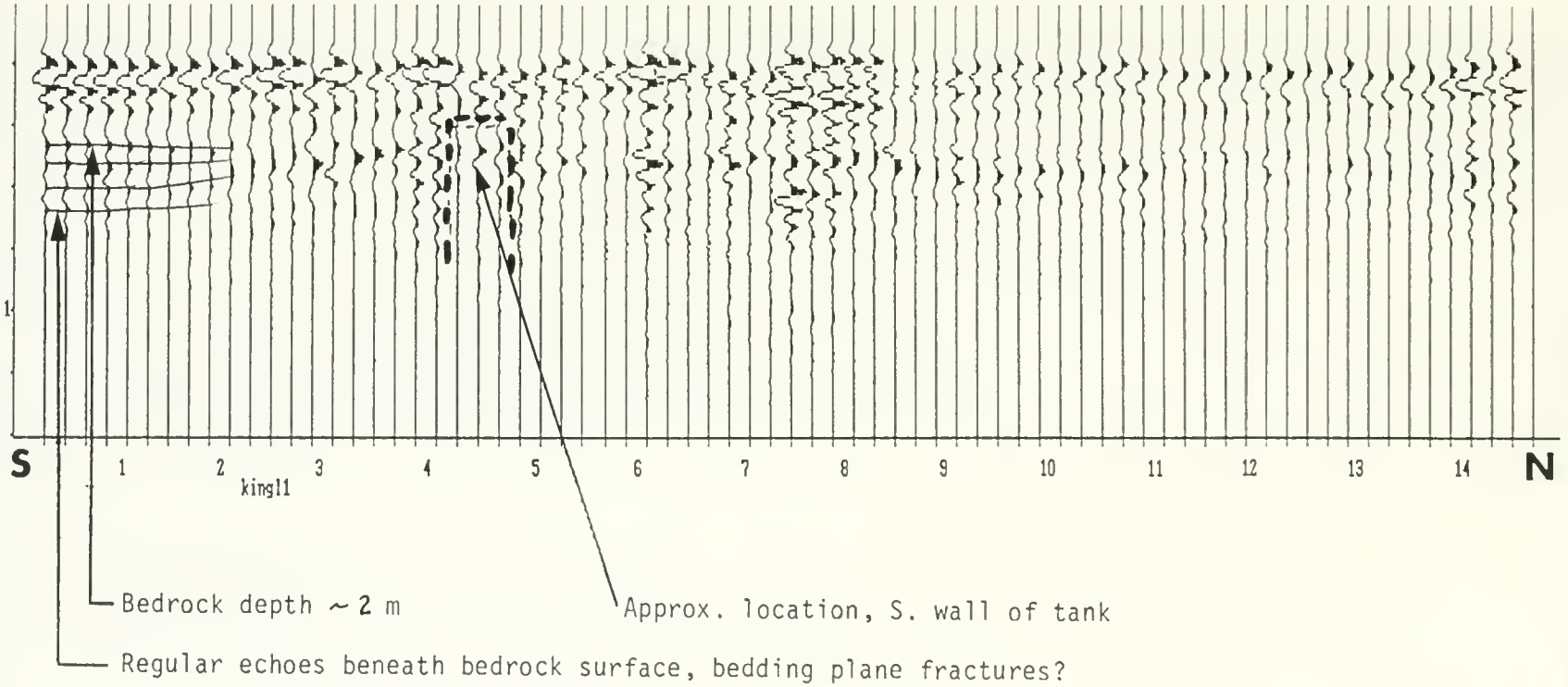
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SITE MAP SHOWING LOCATION OF GROUND PENETRATING RADAR SURVEY LINES

INTERA Technologies

SCALE 1cm = 10.2m

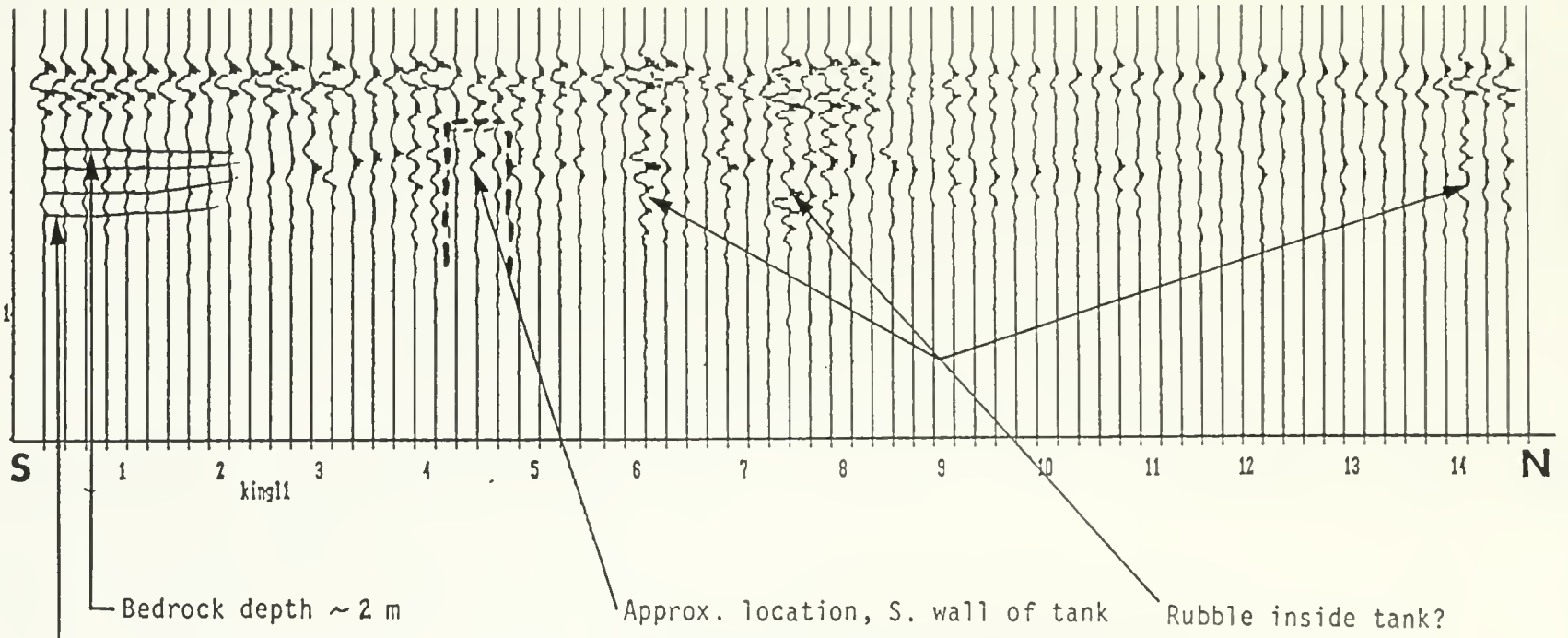
Figure B- 1



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INTERA Technologies

Kingston, Line No. 1
Ground probing radar survey

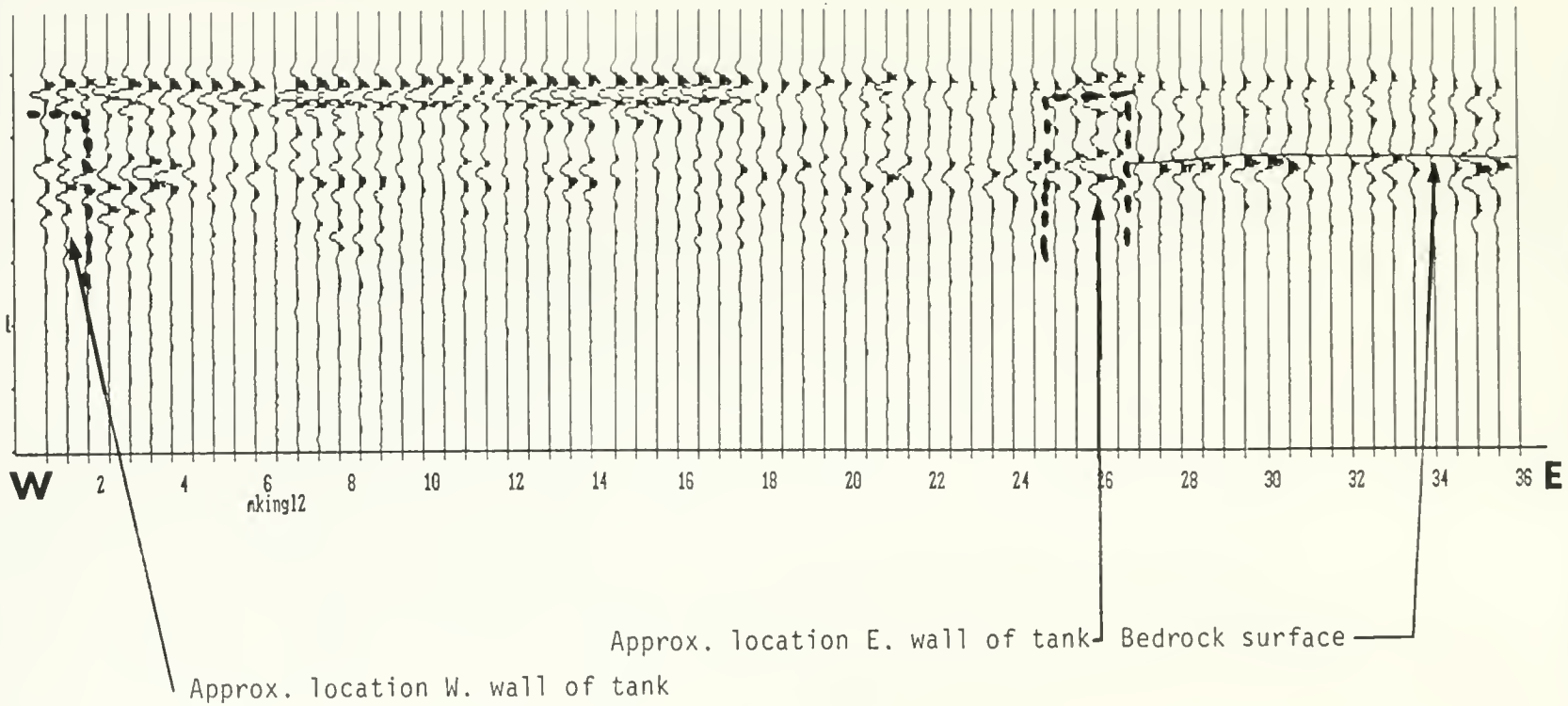


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Revisions	Date

Kingston, Line No. 1
Ground probing radar survey

INTERA Technologies

Figure B-2

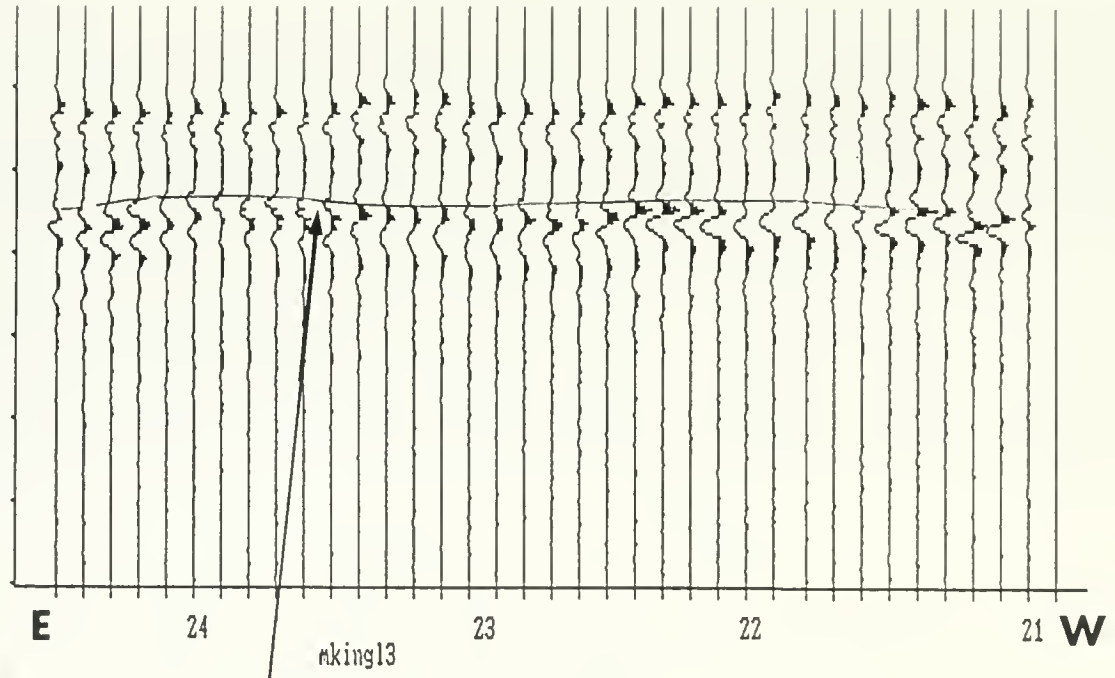


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Revisions	Date

INTERA Technologies

Kingston, Line No. 2
Ground probing radar survey

Figure B-3

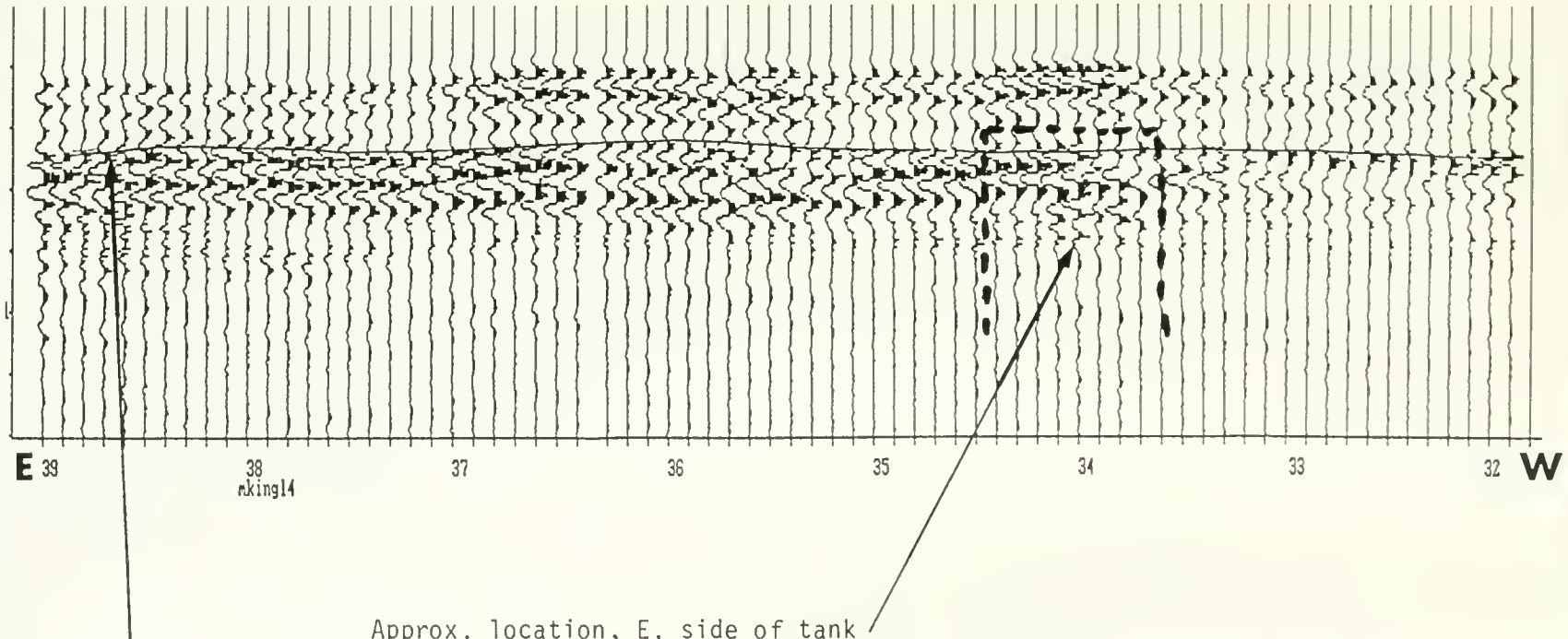


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Kingston, Line No. 3
Ground probing radar survey

INTERA Technologies

Figure B-4

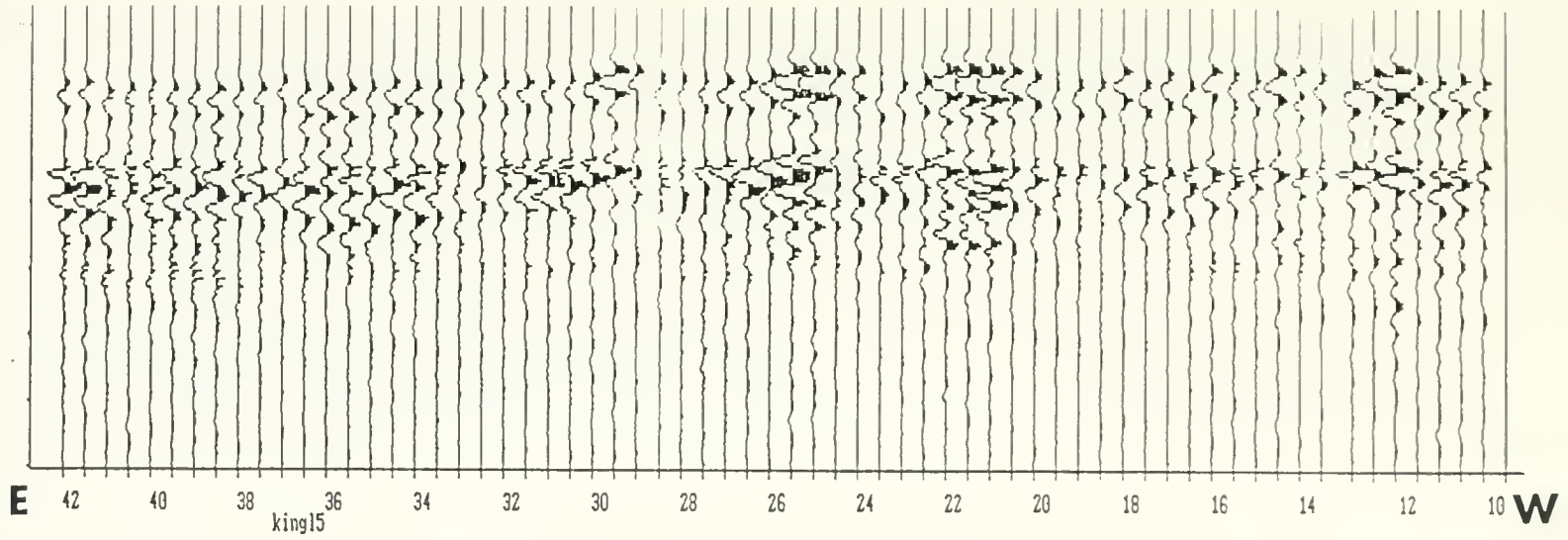


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Revisions	Date

INTERA Technologies

Kingston, Line No. 4
Ground probing radar survey

Figure B-5



Line 4

Line 6

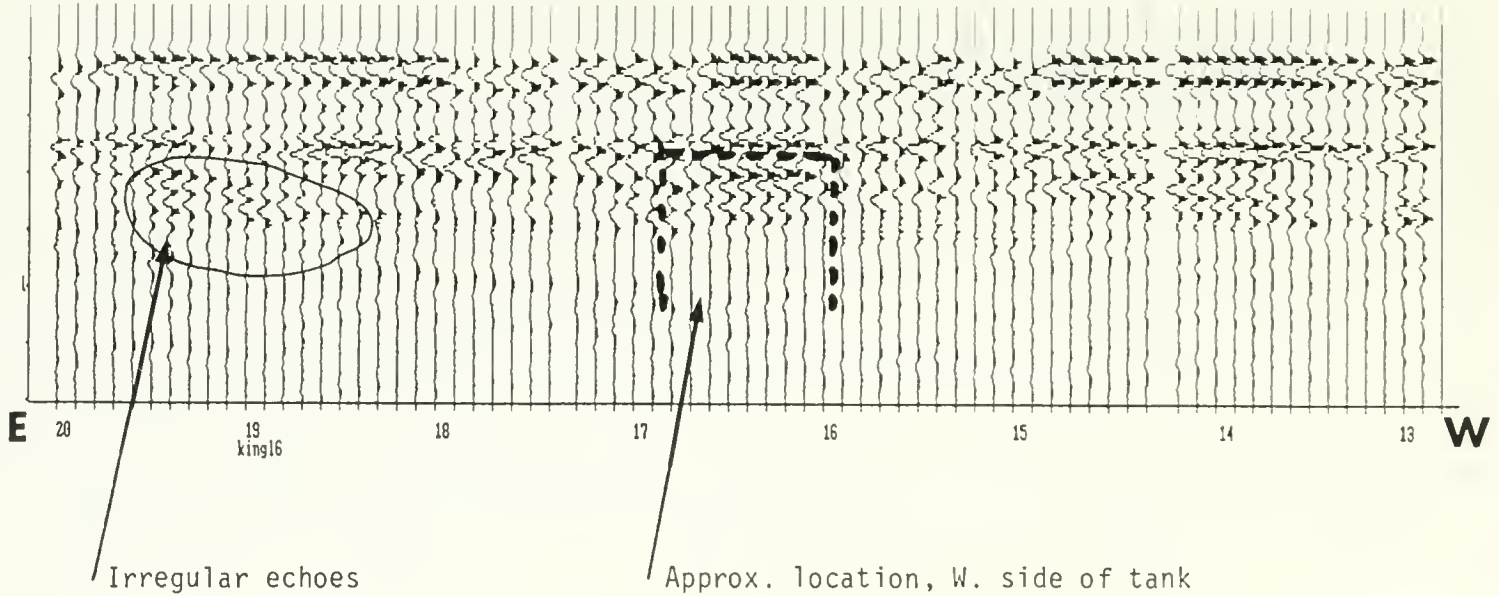
Few continuous echoes - typical of fill

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Revisions	Date

INTERA Technologies

Kingston, Line No. 5
Ground probing radar survey

Figure B-6

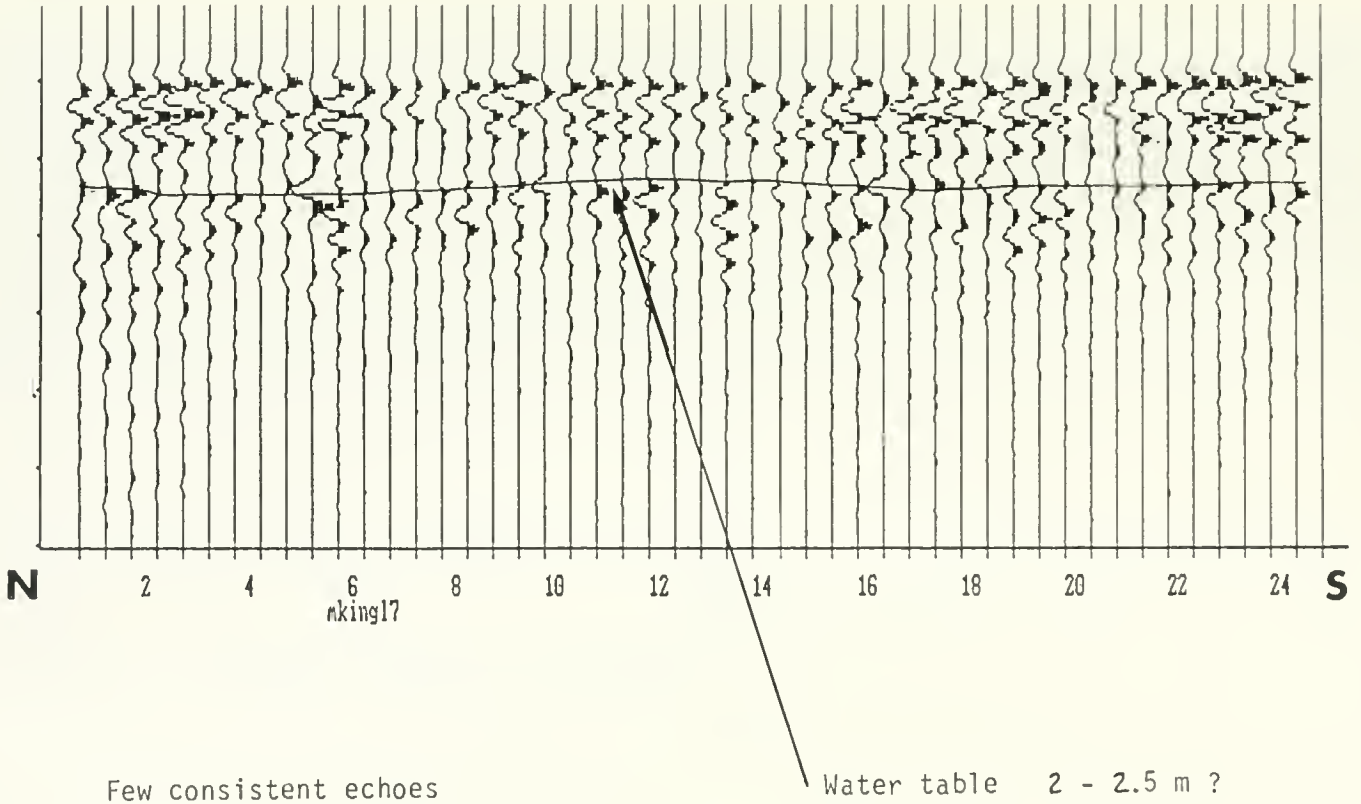


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Checked by	Date
Revisions	Date

Kingston, Line No. 6
Ground probing radar survey

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Figure B-7

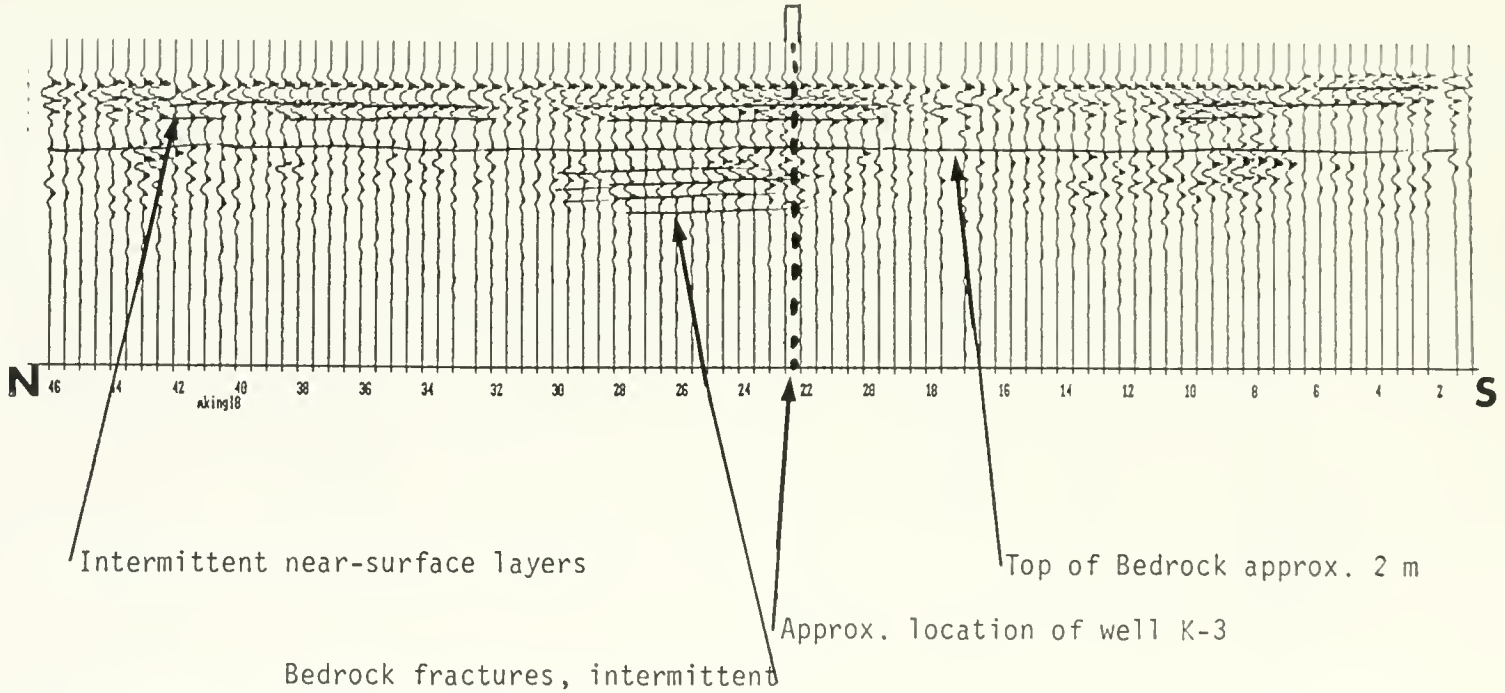


Drawn by	Date
Checked by	Date
Revisions	Date

Kingston, Line No. 7
Ground probing radar survey

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Figure B-8



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Checked by	Date
Revisions	Date

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Kingston, Line No. 8
Ground probing radar survey

Figure B-9

APPENDIX C

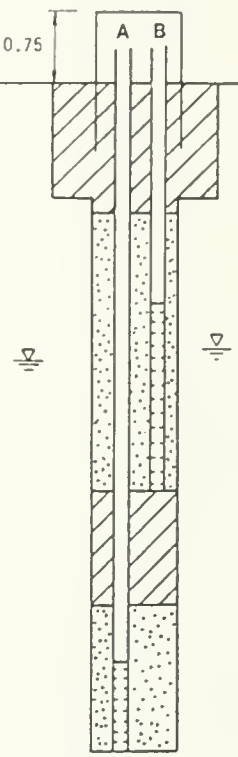
Borehole Logs and Monitoring Well Completion Details

STRATIGRAPHIC AND INSTRUMENTATION LOG

PROJECT NAME AND No.: FORMER GAS PLANT / H88-026	BOREHOLE No.: K - 1
CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT	DATE COMPLETED: 23 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12 in. Auger/HQ Coring
REFERENCE ELEVATION: 78.67 mASL (GROUND SURFACE)	DRILL SUPERVISOR: R.A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	ELEVATION m AMSL
0	SS-1	FILL - gravel, asphalt, cinders, ash	
	SS-2	- grey and black sand - lt. brown clay	76.99
2	CR-1	LIMESTONE - grey, crystalline - fossiliferous - medium bedded - shale seams - styolites	
4	CR-2	- OVM 5-10 ppm on core	
	CR-3		
6	CR-4		
8	CR-5		
10	CR-6		67.77
12		NOTES	
	CR-1	- no evidence of coal tar or odour	
	CR-2	- coal tar on several fractures - brown blebs on fracture surfaces	
	CR-3	- minor coal tar sheen on some fractures	
14	CR-4	- no visible coal tar or sheen	
	CR-5	- " " " " " "	
	CR-6	- " " " " " "	
16			
18			
20			

PIEZOMETER INSTALLATION



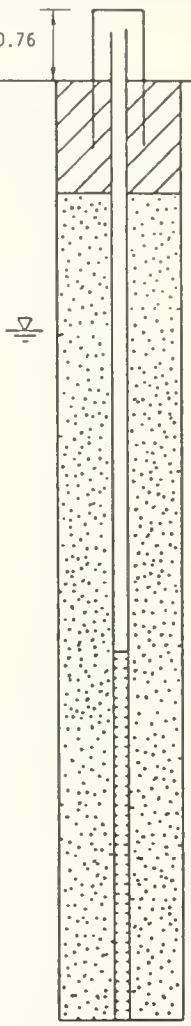
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STRATIGRAPHIC AND INSTRUMENTATION LOG

PROJECT NAME AND No.: FORMER GAS PLANT / H88-026	BOREHOLE No.: K - 2
CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT	DATE COMPLETED: 24 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12 in. AUGER
REFERENCE ELEVATION: 80.12 mASL (GROUND SURFACE)	DRILL SUPERVISOR: R. A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	WATER TABLE
0	SS-1	FILL - dark brown clay - occ. gravel	
1	SS-2	-OVM 3.5 ppm	78.32
2		FILL - no spoon recovery - coarse sand and gravel with large boulders - approx. 1.5 m dia. void created during drilling - filled with limestone gravel during well completion	
3			
4		-OVM 3.5-4.5 on sample	75.92
5	SS-3 SS-4	FILL - sand and gravel - wet	
6			
7	SS-5		
8	SS-6	-OVM 5.0 ppm on sample	
	SS-7	SPOON REFUSAL OVM 15-25 ppm	72.40
		- inferred bottom of tank or bedrock	
9		NOTES SS-3 - slight tar odour 1.83 - 2.44m SS-3 - tar odour on sample SS-6 - tar sheen, strong odour SS-7 - free tar, v. strong odour	
10			

PIEZOMETER INSTALLATION



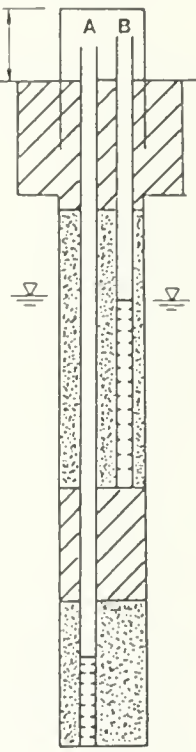
INTERA Technologies Ltd.

STRATIGRAPHIC AND INSTRUMENTATION LOG

PROJECT NAME AND No.: FORMER GAS PLANT 1188-026	BOREHOLE No.: K-3
CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT	DATE COMPLETED: 25 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12IN. HOLLOWSTEM AUGER, HQ CORING
REFERENCE ELEVATION: 78.17 MASL (GROUND SURFACE)	DRILL SUPERVISOR: P.A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	ELEVATION m AMSL
0	SS-1, SS-2	FILL - brown silty clay	
2			76.18
	CR-1	LIMESTONE - OVM 3-8ppm on core - grey, finely crystalline - numerous thin shale seams - most fractures occur at shale seams - sty olites - fossiliferous	
4	CR-2		
	CR-3		
6	CR-4		
8	CR-5	SHALY LIMESTONE	
10	CR-6		
			67.22
12		NOTES	
	CR-1	- minor coal tar odour from 3.0 m to end of run	
	CR-2	- distinct coal tar odour, light brown tar blebs on core	
14	CR-3	- coal tar odour and minor visible sheen on some fractures	
	CR-4	- more coal tar than CR-3	
	CR-5	- v. minor coal tar sheen, may be only from water circ. during drilling	
16			
18			
20			

PIEZOMETER INSTALLATION



INTERA Technologies Ltd.

STRATIGRAPHIC AND INSTRUMENTATION LOG

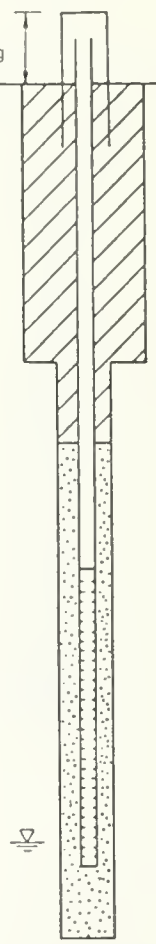
PROJECT NAME AND No.: FORMER GAS PLANT / H88-026	BOREHOLE No.: K - 4
CLIENT: ONTARIO MINISTRY OF THE ENVIROMENT	DATE COMPLETED: 26 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12 in. AUGER / HQ CORING
REFERENCE ELEVATION: 80.88 mASL (GROUND SURFACE)	DRILL SUPERVISOR: R. A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	ELEVATION mAMSL
0	SS-1	FILL - black ashes, cinders, coal, minor red brick frags.	
1	SS-2	- grey clay fill with gravel - limestone chips - OVM up to 10 ppm on sample - fill and boulders	78.66
2			
3	CR-1	LIMESTONE - shaly - green/grey	77.28
4	CR-2	- OVM 5-15 ppm	75.71
5			
6			

NOTES

SS-1 - no odours
SS-2 - visible coal tar on sample
CR-2 - minor coal tar sheen on fractures

PIEZOMETER INSTALLATION



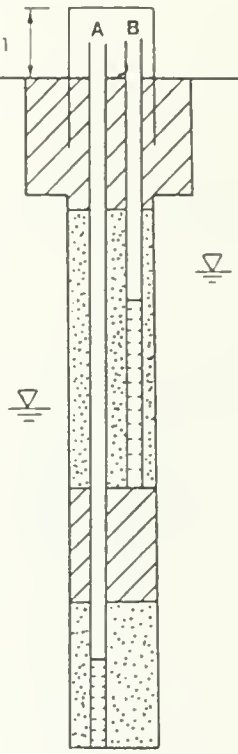
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STRATIGRAPHIC AND INSTRUMENTATION LOG

PROJECT NAME AND No.: FORMER GAS PLANT / H88-026	BOREHOLE No.: K - 5
CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT	DATE COMPLETED: 27 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12 in. AUGER / HQ CORING
REFERENCE ELEVATION: 79.89 mASL (GROUND SURFACE)	DRILL SUPERVISOR: R. A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	ELEVATION m AMSL
0	SS-1, SS-2	FILL - dark brown/black - sandy, some gravel - coal frags., some clay	
2			77.71
4	CR-1, CR-2	SILTSTONE OVM 3- 7 ppm - green/grey - medium bedded - fractures assoc. with shale seams - occ. styolites	
6	CR-3	- OVM 5- 70 ppm on core and drill water	
8	CR-4, CR-5	LIMESTONE - grey - medium bedded - numerous shale seams - styolites	
10	CR-6		69.04
12		NOTES	
14	CR-1	- tar staining on fracture at 2.82 m	
	CR-2	- no visible tar	
	CR-3	- minor tar flecks on fractures	
	CR-4	- minor tar on most fractures, significant tar at 6.71 m	
	CR-5	- minor tar sheen on some fractures	
	CR-6	- minor tar on some fractures - shale seams have absorbed some tar	
16			
18			
20			

PIEZOMETER INSTALLATION



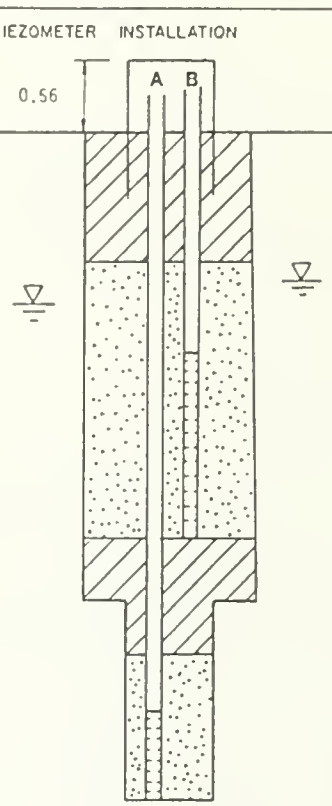
INTERA Technologies Ltd.

STRATIGRAPHIC AND INSTRUMENTATION LOG

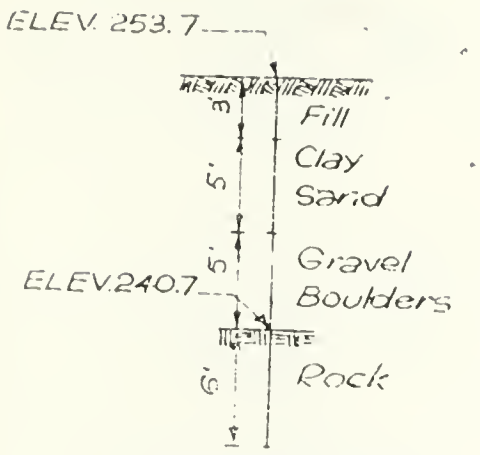
PROJECT NAME AND No.: FORMER GAS PLANT / H88-026	BOREHOLE No.: K - 6
CLIENT: ONTARIO MINISTRY OF THE ENVIRONMENT	DATE COMPLETED: 28 MARCH 1988
LOCATION: KINGSTON, ONTARIO	DRILLING METHOD: 12 in. AUGER / HQ CORING
REFERENCE ELEVATION: 77.38 mASL (GROUND SURFACE)	DRILL SUPERVISOR: R. A. SWEEZEY

DEPTH m BG	SAMPLE AND No.	STRATIGRAPHIC DESCRIPTION AND REMARKS	ELEVATION m AMSL
0	SS-1	FILL - brown sand - sand, gravel, coal, brick, glass, limestone frags.	75.88
2	SS-2	CLAY - dark grey, brown mottling - hard - wood pieces, organics	
4	SS-3 SS-4 SS-5		
6	SS-6		70.88
	SS-7	TILL - sandy with numerous pebbles - wet	69.88
8	CR-1	LIMESTONE - grey, crystalline - medium bedded - thin shale and mud seams - styolites	
10	CR-2	-OVM 3- 70 ppm on core	
	CR-3		66.48
12		NOTES - no contamination found in overburden	
	CR-1	- minor coal tar odour	
	CR-2	- significant coal tar on core	
		- free coal tar, most noticeable around 9.5 m	
14	CR-3	- free coal tar on fractures	
16			
18			
20			

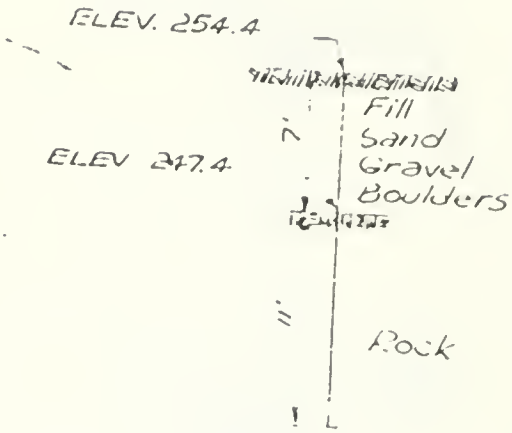
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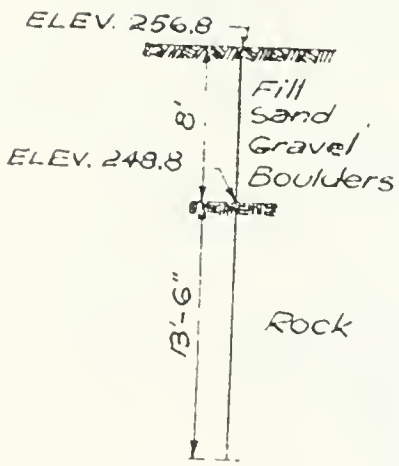
INTERA Technologies Ltd.



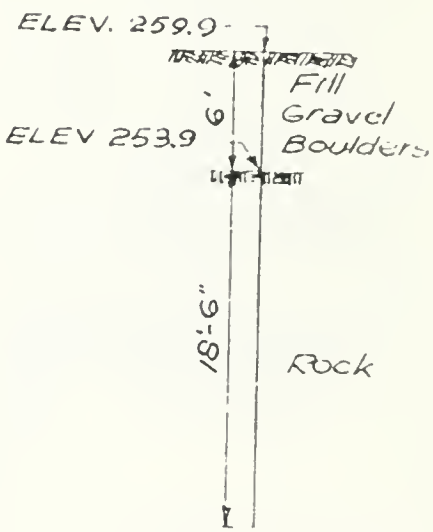
TESTHOLE
№ 31



TESTHOLE
№ 33



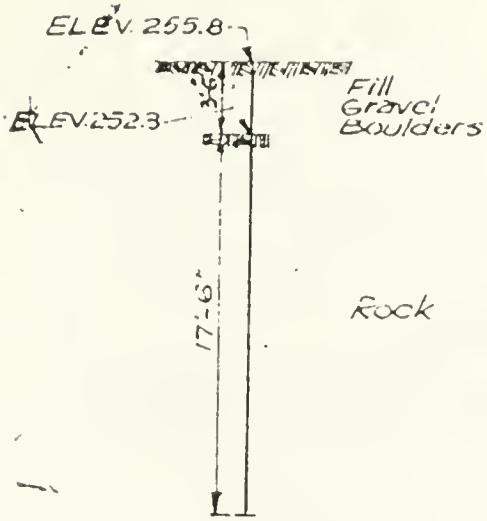
TESTHOLE
№ 34



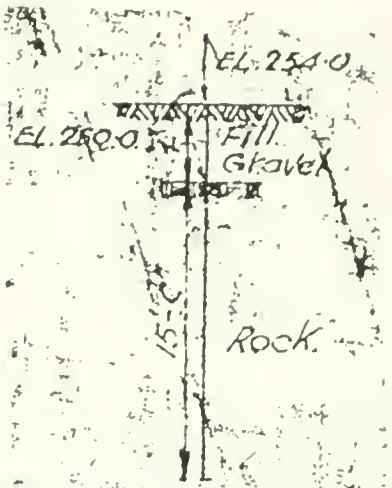
TESTHOLE
№ 35

CITY OF KINGSTON TESTHOLES FROM SEWER MAPS

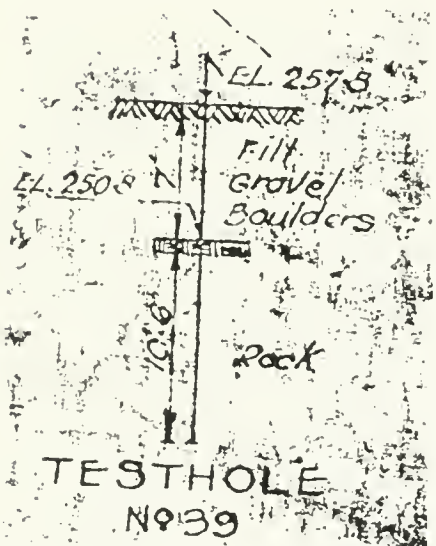
CITY OF KINGSTON TESTHOLES FROM SEWER MAPS



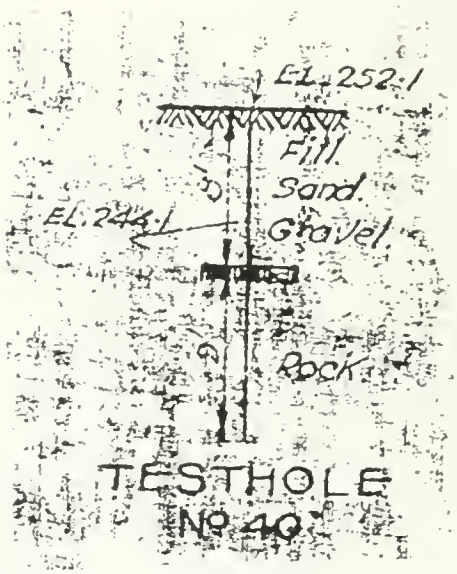
TESTHOLE
Nº 37



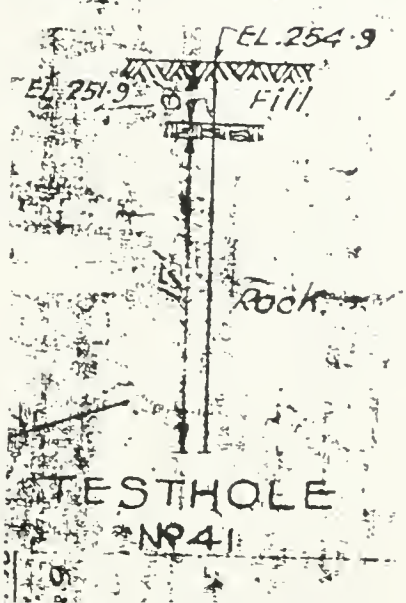
TESTHOLE
Nº 38



TESTHOLE
Nº 39



TESTHOLE
Nº 40



TESTHOLE
Nº 41

INTERA

APPENDIX D

Sediment and Surface Water Analytical Results

Table D-1

Concentration of Inorganic Parameters in Soil Samples (µg/g)

	K-SED-1	K-SED-1
Al	5800	9600
Cr	24	29
Cu	53	1530
Fe	11,800	35,000
Mn	210	400
Ni	12	21
Pb	146	44
Zn	159	114
Ag	<0.5/<1	5.5
Cd	0.5	0.2
CN	0.5	0.1

Values shown with a "/" are results of duplicate analysis.

TABLE D-2 ANALYTICAL RESULTS FOR SEDIMENT SAMPLES

CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOIL

ug/g

COMPOUND	K-SED -1	K-SED -2	MDL	Lab Blank	MDL
ACENAPHTHENE	0.3	-	0.2	-	0.02
ACENAPHTHYLENE	-	-	0.2	-	0.02
ANTHRACENE	0.7	-	0.2	-	0.02
BENZ(A)ANTHRACENE	1.3	-	0.2	-	0.02
BENZO(B) + BENZO(K)FLUORANTHENE	1.8	0.5	0.2	-	0.02
BENZO(A)PYRENE	1.5	0.5	0.2	-	0.02
BENZO(GHI)PERYLENE	1	-	0.4	-	0.04
CHRYSENE	1.4	0.7	0.2	-	0.02
DIBENZ(A,H)ANTHRACENE	-	-	0.4	-	0.04
FLUORANTHENE	1.8	0.8	0.2	-	0.02
FLUORENE	0.4	-	0.2	-	0.02
INDENO(1,2,3-CD)PYRENE	0.8	-	0.4	-	0.04
NAPHTHALENE	-	-	0.2	0.04	0.02
PHENANTHRENE	2.2	0.2	0.2	-	0.02
PYRENE	3	0.7	0.2		0.02

MDL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS

(%)

COMPOUND	K-SED -1	K-SED -2	Lab Blank
D8-NAPHTHALENE	18	26.8	51.3
D10-ANTHRACENE	70.1	54.9	74.6
D10-FLUORANTHENE	67.5	72.5	70.3
D12-PERYLENE	84.3	100	61.6

* = Recovery not determined due to necessary dilution of extract.

Table D-3

CONCENTRATION OF MONOCYCLIC AROMATIC HYDROCARBONS IN SOIL
ug/g

COMPOUND	K-SED-1	K-SED-2	LAB BLANK	MDL
BENZENE	-	-	-	0.04
CHLOROBENZENE	-	-	-	0.04
1,2-DICHLOROBENZENE	-	-	-	0.06
1,3-DICHLOROBENZENE	-	-	-	0.06
1,4-DICHLOROBENZENE	-	-	-	0.06
ETHYLBENZENE	-	-	-	0.04
A-METHYLSTYRENE	-	-	-	0.02
METHYLSTYRENE ISOMERS	-	-	-	0.02
MESITYLENE	-	-	-	0.02
TOLUENE	0.06	-	-	0.04
M+P-XYLENE	TR	-	-	0.06
O-XYLENE	0.02	-	-	0.02
STYRENE	-	-	-	0.04
OTHER AROMATIC COMPOUNDS	0.06	-	-	0.02

MDL = METHOD DETECTION LIMITS

OTHER AROMATIC COMPOUNDS = Total concentration of trimethylbenzenes using the response factor of mesitylene.

Table D-4 Surface Water Quality Analyses - Inorganic

Lab Number		K-Surf-1		K-Surf-2		K-Surf-3	
Constituent		Water soluble*	Total	Water soluble*	Total	Water soluble*	Total
Sodium	mg/L	6.6		6.4		6.6	
Potassium	mg/L	1.3		1.3		1.4	
Calcium	mg/L	29		33		29	
Magnesium	mg/L	6.6		6.8		6.7	
Hardness	mg/L (as CaCO3)	100		110		100	
Alkalinity	mg/L (as CaCO3)	89		93		89	
Sulfate	mg/L	14		18		14	
Chloride	mg/L	11		16		12	
Silica	mg/L	<0.5		<0.5		<0.5	
o-Phosphate	mg/L	<0.01		<0.01		<0.01	
Nitrate + Nitrite	mg/L (as N)	0.10		0.16		0.11	
Ammonia	mg/L (as N)	<0.05		<0.05		<0.05	
Iron	mg/L	0.03	0.06	0.03	0.06	0.03	0.08
Manganese	mg/L	<0.01	0.04	<0.01	0.03	<0.01	0.04
Copper	mg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Color, true	Color Units	20		11		10	
Turbidity	N.T.U.	1.4		1		1.4	
Conductivity	µmho/cm @ 25 C	238		267		242	
pH		8.1		8.4		8.0	
Total Organic Carbon	mg/L	5.2		4.4		4.8	
Cation Sum	meq/L	2.32		2.62		2.33	
Anion Sum	meq/L	2.39		2.70		2.42	
Ion Ratio		0.97		0.97		0.96	
% Difference		1.5		1.5		1.0	
TDS (ion sum)	mg/L	122		140		124	
Conductivity (calc)	µmho/cm @ 25 C	241		270		244	
pH	(saturation @ 4 C)	8.31		8.24		8.31	
Langelier Index	@ 4 C	-0.21		0.16		-0.31	
Bicarbonate	mg/L (as CaCO3)	88		91		88	
Carbonate	mg/L (as CaCO3)	1.0		2.1		0.8	

* All results based on sample centrifuged at 2000 RPM for 30 minutes except pH, turbidity and conductivity, and 'total' metals (iron, manganese, copper and zinc).

TABLE D-5 ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES

CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN WATER
ug/L

COMPOUND	K-SURF -1	K-SURF -2	K-SURF -3	Lab Blank	MDL
ACENAPHTHENE	-	-	-	-	0.05
ACENAPHTHYLENE	-	-	-	-	0.05
ANTHRACENE	-	-	-	-	0.05
BENZ(A)ANTHRACENE	-	-	-	-	0.05
BENZO(B) + BENZO(K)FLUORANTHENE	-	-	-	-	0.05
BENZO(A)PYRENE	-	-	-	-	0.05
BENZO(GHI)PERYLENE	-	-	-	-	0.1
CHRYSENE	-	-	-	-	0.05
DIBENZ(A,H)ANTHRACENE	-	-	-	-	0.1
FLUORANTHENE	-	-	-	-	0.05
FLUORENE	-	-	-	-	0.05
INDENO(1,2,3-CD)PYRENE	-	-	-	-	0.1
NAPHTHALENE	-	-	-	-	0.05
PHENANTHRENE	-	-	-	-	0.05
PYRENE	-	-	-	-	0.05

MDL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS
(%)

COMPOUND	K-SURF -1	K-SURF -2	K-SURF -3	Lab Blank
D8-NAPHTHALENE	66.3	67.1	68.7	67.6
D10-ANTHRACENE	90.4	85.6	96.3	93
D10-FLUORANTHENE	80	63.1	64.8	81.9
D12-PERYLENE	83.1	82.4	98.2	100

APPENDIX E

Groundwater Analytical Results

TABLE E-1 FORMER GAS PLANT STUDY KINGSTON, ONTARIO
GEOCHEMICAL FIELD PARAMETERS

WELL NUMBER	pH	CONDUCTIVITY (umho)	TEMPERATURE (deg C)
K-1A	7.2	1100	10.0
K-1B	6.7	2100	11.0
K-2	7.5	720	8.0
K-3A	7.2	900	13.5
K-5A	NT	NT	NT
K-6A	6.9	1000	10.0

NT = NOT TAKEN

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va, Ontario
X5
749-2220 Telex 053-3233

BONDAR-CLEGG

Certificate
of Analysis

Table E-2 Groundwater Inorganic Analytical Results

REPORT: 088-50244.4 | PROJECT: HOME | PAGE 1A

SAMPLE NUMBER	ELEMENT UNITS	Zn PPM	pH	Ca PPM	Mg PPM	Na PPM	K PPM	Alk PPM	HCO3 PPM	SO4 PPM	H2S PPM	Cl PPM
K1A-1-S		<0.05	7.50	157	48	78	5	340	414	46	15	261
K1B-1-S		<0.05	7.19	301	47	309	12	446	544	120	18	453
K2-1-S		<0.05	7.72	118	24	74	14	290	353	13	15	183
K3A-1-S		<0.05	7.61	81	41	79	10	370	451	45	15	101
K5A-1-S		<0.05	7.80	159	54	79	9	316	385	55	15	270
K6A-1-S		<0.05	7.24	188	54	58	7	571	696	45	15	167

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Table E-2 (cont'd)

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SAMPLE NUMBER	ELEMENT UNITS	CN- PPB	NH3 PPB	N tot PPB	COD mg/L	C Org. PPM	Phen PPB	Al PPB	Cd PPB	Cr PPB	Cu PPB	Fe tot PPB
K1A-1-S		<0.1	<0.10		24	3.2	0.100	0.59	<0.01	<0.05	<0.05	0.50
K1B-1-S		<0.1	<0.10		9	3.5	<0.002	0.49	<0.01	<0.05	<0.05	0.20
K2-1-S		0.3	<0.10		15	5.7	0.020	0.49	<0.01	<0.05	<0.05	0.60
K3A-1-S		<0.1	<0.10		113	8.8	0.211	1.00	<0.01	<0.05	<0.05	0.30
K5A-1-S		<0.1	<0.10		30	5.2	0.430	0.19	<0.01	<0.05	<0.05	0.20
K6A-1-S		<0.1	<0.10		405	6.4	0.102	0.11	<0.01	<0.05	<0.05	0.60

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Table E-2 (cont'd)

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SAMPLE NUMBER	ELEMENT UNITS	Pb PPM	Au PPB	Ni PPM
K1A-1-5		<0.05	0.10	<0.05
K1B-1-5		0.10	0.10	<0.05
K2-1-5		<0.05	0.10	<0.05
K3A-1-5		<0.05	<0.05	<0.05
K5A-1-5		<0.05	<0.05	<0.05
K6A-1-5		<0.05	0.20	<0.05

Table E-3

CONCENTRATION OF VOLATILE PRIORITY POLLUTANTS IN WATER
ug/L

COMPOUND	K6A-1	MDL	K1A-1	K3A-1	K5A-1	MDL	K1B-1	K2-1
BENZENE	26000	200	33000	65000	25000	100	130	1200
BROMODICHLOROMETHANE	-	200	-	-	-	100	-	-
BROMOFORM	-	400	-	-	-	200	-	-
BROMOMETHANE	-	3200	-	-	-	1600	-	-
CARBON TETRACHLORIDE	-	400	-	-	-	200	-	-
CHLOROBENZENE	-	200	-	-	-	100	-	-
CHLOROETHANE	-	2000	-	-	-	1000	-	-
2-CHLOROETHYL VINYL ETHER	-	2000	-	-	-	1000	-	-
CHLOROFORM	-	200	-	-	450	100	-	-
CHLOROMETHANE	-	10000	-	-	-	5000	-	-
DIBROMOCHLOROMETHANE	-	200	-	-	-	100	-	-
1,2-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,3-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,4-DICHLOROBENZENE	-	200	-	-	-	100	-	-
1,1-DICHLOROETHYLENE	-	200	-	-	-	100	-	-
1,1-DICHLOROETHANE	-	200	-	-	-	100	-	-
1,2-DICHLOROETHANE	-	400	-	-	-	200	-	-
TRANS-1,2-DICHLOROETHYLENE	-	200	-	-	-	100	-	-
DICHLOROMETHANE	-	3000	-	-	-	1500	-	-
1,2-DICHLOROPROPANE	-	200	-	-	-	100	-	-
CIS-1,3-DICHLOROPROPENE	-	200	-	-	-	100	-	-
TRANS-1,3-DICHLOROPROPENE	-	200	-	-	-	100	-	-
ETHYLBENZENE	10000	200	1000	2900	280	100	160	290
A-METHYLSTYRENE	-	200	-	-	-	100	-	-
METHYLSTYRENE ISOMERS	1100	200	800	580	420	100	89	176
MESITYLENE	-	200	-	-	-	100	-	-
1,1,2,2-TETRACHLOROETHANE	-	400	-	-	-	200	-	-
TETRACHLOROETHYLENE	-	200	-	-	-	100	-	-
TOLUENE	22000	400	19000	24000	9800	200	170	450
1,1,1-TRICHLOROETHANE	-	400	-	-	-	200	-	-
1,1,2-TRICHLOROETHANE	-	200	-	-	-	100	-	-
TRICHLOROETHYLENE	-	200	-	-	-	100	-	-
TRICHLOROFLUOROMETHANE	-	400	-	-	-	200	-	-
M+P-XYLENE	5700	200	3200	4000	1100	100	190	220
O-XYLENE	2100	200	1100	1700	550	100	120	100
VINYL CHLORIDE	-	2400	-	-	-	1200	-	-
OTHER AROMATIC COMPOUNDS	2600	200	600	730	190	100	220	320
STYRENE	5500	400	6900	6000	5000	200	110	880

MDL = METHOD DETECTION LIMITS

OTHER AROMATIC COMPOUNDS = Total concentration of trimethylbenzenes using the response factor of mesitylene.

TABLE E-4 CONCENTRATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN WATER
ug/L

OMPOUND	K1a-1	K1b-1	K5a-1	K6a-1	MDL	K3a-1	Lab Blank	MDL	K2-1	MDL
CENAPHTHENE	12	42	19	100	0.8	16	-	0.05	51	0.05
CENAPHTHYLENE	33	120	40	2500	0.8	260	-	0.05	110	0.05
NTHRACENE	11	13	13	290	0.8	19	-	0.05	18	0.05
ENZ(A)ANTHRACENE	0.2	0.3	0.5	110	0.8	0.6	-	0.05	0.7	0.05
ENZO(B) + BENZO(K)FLUORANTHENE	-	0.1	0.1	66	0.8	0.2	-	0.05	0.2	0.05
ENZO(A)PYRENE	-	0.1	0.2	65	0.8	0.2	-	0.05	0.2	0.05
ENZO(GHI)PERYLENE	-	-	-	27	1.5	-	-	0.1	TR	0.1
HRYSENE	0.2	0.3	0.3	75	0.8	0.5	-	0.05	0.4	0.05
IBENZ(A,H)ANTHRACENE	-	-	-	11	1.5	-	-	0.1	-	0.1
LUORANTHENE	2.1	3.7	2.3	160	0.8	4.5	-	0.05	4	0.05
LUORENE	42	52	42	370	0.8	48	-	0.05	40	0.05
NDENO(1,2,3-CD)PYRENE	-	-	-	26	1.5	-	-	0.1	TR	0.1
APHTHALENE	15	56	24	1100	0.8	210	-	0.05	270	0.05
HENANTHRENE	53	55	55	1000	0.8	78	-	0.05	69	0.05
YRENE	3.1	5.5	-	280	0.8	5.8	-	0.05	6.3	0.05

DL = METHOD DETECTION LIMIT

RECOVERY OF SURROGATE STANDARDS
(%)

OMPOUND	K1a-1	K1b-1	K5a-1	K6a-1	K3a-1	Lab Blank	K2-1
8-NAPHTHALENE	*	*	*	*	*	57.8	*
10-ANTHRACENE	100	100	100	100	100	90.7	100
10-FLUORANTHENE	76.5	67.8	80.9	71.6	68.7	79.2	76.7
12-PERYLENE	63.7	57.9	74.5	**	62.4	81.6	52.9

* = Recovery not determined due to high concentration of native naphthalene.